CHAPTER 7

CURRENT WATER REQUIREMENTS

The projection of future water requirements in the IID is best done by first defining the current and historical requirements as accurately as records allow. This action creates a sound data base from which extrapolations of future demands can be made. Chapter 7 presents the background data on water required and sets the stage for the projections discussed in Chapter 8. The initial impetus of the analysis was directed at determining the critical variables affecting demand and then synthesizing the scenarios using different values of these parameters to define a probable range of demand. Based on these scenarios, current water diversion requirements were derived. The current water requirements within the IID have been divided for this report into three major categories:

(1) Losses within the transmission system.

(2) Agricultural requirements, which includes an accounting of the distribution system and on-farm operation.

(3) Municipal, industrial, and other nonfarm beneficial uses such as maintenance of wildlife habitats.

7.1 DEMAND MODELING METHODOLOGY

The current water requirements are estimated, based on an evaluation of the past 10 years of records (1975-1984). Currently, 98% of IID water is used for agriculture. Therefore, for purposes of developing the range of current water requirements, the list of critical variables will be limited to those that affect agricultural water demands. Maximum, minimum, and baseline values of nonagricultural requirements will not be calculated. Instead, the respective historical values will be used, based on the 1975-1984 records.

The primary factors that have a direct influence on the amount of water delivered for agricultural purposes include:

(1) Weather
(2) Total area devoted to agriculture
(3) Cropping pattern
(4) Salinity of supply water

Each of these factors has varied in the past and is expected to vary in the future. Records for the historical variations are readily available and are used in determining the range over which each factor may vary. With the exception of the area devoted to agriculture, these various factors relate directly to the unit rate of applied water in acre-feet per acre.

The IID's historical records depicting the distribution of the total gross acreage within the IID was summarized for 1975-1984 and are presented in Table 7-1. Based on the historical data from the last 10 years, over 80% of the total area receiving water has been farmland, and the amount of land being reclaimed has been increasing.

7.1.1 BASELINE DEMAND SCENARIO

The most probable demand scenario for the IID is primarily a function of crop pattern. The crop pattern, in terms of acreage of different crops, has varied considerably over the base period of 1975-1984. Table 7-2 presents the acreage of each crop over the base period. These crops are grouped into three major categories: garden crops, field crops, and permanent crops. The total acreage that is cropped (shown in Table 7-2) reflects multiple cropping practices common in the District. The actual area farmed varies from year to year but averages approximately 460,000 acres. The variation of these major categories over time is depicted graphically in Figure 7-1. When individual crops are reviewed, the variation over time becomes more dramatic, and Figure 7-2 shows the historical acreages of five major crops (alfalfa, cotton, lettuce, sugar beets, and wheat) over the base period.

To determine a reasonable baseline scenario of crop pattern, several averages of the base period data were calculated:

(1) A 10-year arithmetic average

(2) An arithmetic average of the three most recent years computed as:

(1984 + 1983 + 1982)/3 = 3-year average

(3) A weighted average of the five most recent years, which effectively places the greatest emphasis on the most recent year and the least amount of emphasis on the past years successively, is computed as the following example illustrates:

(1984 x 10) + (1983 x 8) + (1982 x 6) + (1981 x 5) + (1980 x 4)/33
= 5-year weighted average

These calculated averages are included on Table 7-2. Reviewing these averages, it was decided that the 5-year weighted average was the most representative of current trends and that it should be adopted as the baseline scenario for crop pattern. It was further decided to consolidate the number of crops to a more manageable number. Each crop with an average of over 1,000 acres over the 10-year base period was kept as a separate category, like numbers were grouped, and the remaining crops were placed in miscellaneous categories that were compatible with their unit water requirements. The results of this consideration are presented in Table 7-3.

The calculation of the agricultural water demand for the baseline scenario is based on the representative crop pattern discussed above, historical average salinity of water diverted by the district, and typical climatic conditions.

Table 7-1 - Summary of Area Served (1975-1984)

Land Use	1975	1976	1977	1978	1979	1980	1981	1982	1983[a]	1984	Max	Min	Average		
													10-yr	3-yr	5-yr
Field crops	453,656	482,084	439,067	431,302	433,135	448,464	464,516	445,372	358,131	389,006	482,084	358,131	434,473	397,503	410,417
Garden crops	83,476	79,480	74,574	84,715	88,854	87,343	85,155	88,469	101,141	88,258	101,141	74,574	86,147	92,623	90,838
Permanent crops	15,470	16,126	14,724	13,595	13,562	13,802	14,279	18,602	22,859	18,892	22,859	13,562	16,191	20,118	18,485
Total acres of crops	552,602	577,690	528,365	529,612	535,551	549,609	563,950	552,443	484,131	496,156	577,690	482,131	534,479	510,243	519,741
Total duplicate crops	129,466	154,830	105,551	115,371	116,414	128,679	136,948	133,113	61,089	96,223	154,830	61,089	117,768	96,808	104,517
Total net acres in crops	423,136	422,860	422,814	414,241	419,137	420,930	427,002	419,330	421,042	399,933	427,002	399,933	419,043	413,435	415,224
Area being reclaimed: leached	581	465	300	568	184	1,000	1,112	3,959	5,178	4,271	5,178	184	1,762	4,469	3,559
Net area irrigated	423,717	423,325	423,114	414,809	419,321	421,930	428,114	423,289	426,220	404,204	428,114	404,204	420,804	417,904	418,783
Area farmable but not farmed during year (fallow land)	53,144	53,268	53,480	60,808	57,892	57,190	51,193	58,644	72,297	77,467	77,467	51,193	59,538	69,469	66,353
Total area farmable	476,861	476,593	476,594	475,617	477,213	479,120	479,307	481,933	498,517	481,671	498,517	475,617	480,343	487,374	485,135
Area of farms in homes, feedlots, corrals, cotton gins, experimental farms, and industrial areas	13,300	13,231	12,791	13,847	13,564	13,896	13,905	13,903	13,646	13,771	13,905	12,791	13,585	13,773	13,800
Areas in cities, towns, airports, cemeteries, fairgrounds, golf courses, recreational parks and lakes, and rural schools, less area being farmed	12,239	12,424	12,442	12,841	16,006	14,101	14,113	14,508	16,047	16,308	16,308	12,239	14,103	15,621	15,317
Total area receiving water	502,400	502,248	501,827	502,305	506,783	507,117	507,325	510,344	528,210	511,750	528,210	501,827	508,031	516,768	514,253
Area in drains, canals, rivers, railroads, and roads	71,515	71,428	73,442	73,252	73,278	73,222	73,161	73,513	74,018	74,056	74,056	71,428	73,089	73,862	73,711
Area below -230 ft Salton Sea reserve boundary and area covered by Salton Sea, less area receiving water	36,628	36,873	39,379	39,411	39,419	39,417	39,417	39,417	39,481	39,417	39,481	36,628	38,886	39,438	39,433
Area in Imperial Unit not entitled to water	63,933	63,933	63,933	63,933	63,933	63,933	63,933	63,933	63,933	63,933	63,933	63,933	63,933	63,933	63,933
Undeveloped area of Imperial, West Mesa, and Pilot Knob units	300,611	300,605	296,506	296,186	291,674	291,478	291,425	288,054	269,619	286,105	300,611	269,619	291,226	281,259	283,920
Total acreage included - all units	975,087	975,087	975,087	975,087	975,087	975,167	975,261	975,261	975,261	975,261	975,261	975,087	975,165	975,261	975,250
Acreage not included - all units	87,203	87,203	87,203	87,203	87,203	87,123	87,029	87,029	87,029	87,029	87,203	87,029	87,125	87,029	87,040
Total gross acreage within District boundaries	1,062,290	1,062,290	1,062,290	1,062,290	1,062,290	1,062,290	1,062,290	1,062,290	1,062,290	1,062,290	1,062,290	1,062,290	1,062,290	1,062,290	1,062,290

Note: Alfalfa acreage reduced by factor of 0.793 per DWR, 1981.
[a]IID garden crop acreage reported for 1983, modified per Imperial Valley Agricultural Commissioners crop acreage records.
Source: IID Water Reports, 1975-1984.

Table 7-2 - IID Crop Acreages (1975-1984)

	1975	1976	1977	1978	1979	1980	1981	1982	1983[a]	1984	Max	Min	Average 10-yr	Average 3-yr	Average 5-yr wtd
Garden Crops															
Beans	0	0	0	0	0	50	20	165	79	0	165	0	31	81	58
Blackeyed peas	0	0	0	0	0	0	0	0	85	0	85	0	9	28	21
Broccoli	773	1,302	1,860	2,359	2,756	2,368	2,466	2,306	5,194	5,050	5,194	773	2,643	4,183	3,869
Broccoli (seed)	17	15	0	73	44	75	35	40	258	258	258	0	82	185	162
Cabbage	319	198	230	405	754	938	510	444	31	350	938	31	418	275	385
Cabbage, chinese	0	0	0	0	0	13	3	22	32	9	32	0	8	21	17
Cabbage (seed)	1	73	11	0	38	24	25	198	37	0	198	0	41	78	52
Carrots	5,988	7,572	4,394	6,489	9,211	7,595	6,605	8,917	10,008	10,053	10,053	4,394	7,683	9,659	9,015
Carrots, (seed)	22	70	35	109	45	89	0	218	104	36	218	0	73	119	87
Cauliflower	5	94	0	0	152	211	179	84	151	942	942	0	182	392	390
Cauliflower (seed)	45	8	13	18	18	94	60	20	27	27	94	8	33	25	39
Celery	0	0	0	80	139	260	551	533	161	383	551	0	211	359	367
Chicory	0	0	190	195	101	9	3	6	0	0	195	0	50	2	3
Chicory (seed)	0	0	0	7	0	0	0	0	0	0	7	0	1	0	0
Collards	0	0	0	0	0	28	53	25	0	0	53	0	11	8	16
Collards (seed)	33	0	0	0	14	0	0	0	0	0	33	0	5	0	0
Cucumbers	981	364	523	534	362	353	173	155	137	146	981	137	373	146	175
Dill	0	0	0	0	14	10	36	0	0	0	36	0	6	0	7
Dill (seed)	0	0	0	22	0	0	0	0	0	0	22	0	2	0	0
Ear corn	4	273	297	1,052	620	127	2	658	510	809	1,052	2	435	659	504
Eggplant	0	0	0	0	0	0	4	2	18	0	18	0	2	7	5
Endive	20	0	0	0	0	25	0	0	0	0	25	0	5	0	3
Endive (seed)	22	0	7	0	0	0	0	18	18	0	22	0	7	12	8
Fava beans	0	0	0	0	5	30	20	54	27	0	54	0	14	27	23
Fennel	0	0	0	0	0	0	0	3	3	0	3	0	1	2	1
Flowers	0	0	0	6	12	487	111	229	187	262	487	0	129	226	242
Flowers (seed)	0	3	0	16	0	0	0	0	79	79	79	0	18	53	43
Garlic	1,395	499	380	658	584	840	159	306	376	523	1,395	159	572	402	431
Gourds	0	0	0	14	0	0	0	0	0	0	14	0	1	0	0
Herbs, mixed	40	5	1	0	8	0	9	52	55	51	55	0	22	53	40
Herbs (seed)	14	31	24	28	4	8	157	26	67	111	157	4	47	68	79
Lettuce	44,912	44,420	39,230	41,596	43,629	43,799	36,997	31,086	38,508	26,772	44,912	26,772	39,095	32,122	34,015
Lettuce, butter	0	0	0	0	0	153	35	0	0	0	153	0	19	0	24
Lettuce, chinese	0	0	0	16	12	0	30	0	0	35	35	0	9	12	15
Lettuce, red	0	0	0	0	0	93	35	0	0	0	93	0	13	0	17
Lettuce, romaine	113	80	18	26	88	79	143	0	0	0	143	0	55	0	31
Lettuce (seed)	118	0	8	5	0	239	2	77	382	382	382	0	121	280	252
Melons															
Cantaloupes, fall	0	0	2,443	4,884	3,845	4,858	7,680	6,547	7,635	5,110	7,680	0	4,300	6,431	6,342
Cantaloupes (seed)	45	5	48	0	0	0	75	44	202	157	202	0	58	134	116
Cantaloupes, spring	7,559	9,169	8,003	8,240	6,582	6,263	6,877	7,473	11,403	10,216	11,403	6,263	8,179	9,697	9,020
Casaba, fall	0	27	16	451	217	715	215	41	18	23	715	0	172	27	138
Casaba, spring	0	0	0	0	16	79	0	0	170	152	170	0	42	107	97
Crenshaw, fall	363	421	315	468	200	756	513	873	366	578	873	200	485	606	592
Crenshaw, spring	0	0	4	259	91	48	39	50	49	94	259	0	63	64	61
Honeydew, fall	842	655	985	1,452	1,276	724	1,648	2,547	1,046	2,185	2,547	655	1,336	1,926	1,716
Honeydew (seed)	0	0	0	3	0	0	0	0	0	24	24	0	3	8	7
Honeydew, spring	0	0	0	18	86	31	156	370	388	140	388	0	119	299	231
Kava melons	0	0	0	0	0	0	0	10	21	4	21	0	4	12	8
Mixed, fall	60	7	0	62	88	211	225	662	860	953	953	0	313	825	677
Mixed, spring	0	0	0	0	0	74	8	135	270	115	270	0	60	173	135
Watermelons	2,472	1,964	3,146	1,022	3,136	3,215	3,917	5,354	4,972	4,656	5,354	1,022	3,385	4,994	4,573
Watermelons (seed)	0	20	20	15	0	77	70	25	200	240	240	0	67	155	146

Table 7-2 (Contd)

	1975	1976	1977	1978	1979	1980	1981	1982	1983[a]	1984	Max	Min	Average 10-yr	Average 3-yr	Average 5-yr wtd
Garden Crops (Contd)															
Mung beans	0	0	0	0	0	0	105	33	0	0	105	0	14	11	22
Mustard	310	243	212	155	242	223	179	148	38	19	310	19	177	68	96
Mustard (seed)	0	0	5	33	20	121	70	209	60	25	209	0	54	98	85
Okra	23	20	0	36	40	22	14	188	96	146	188	0	59	143	106
Okra (seed)	45	0	0	67	106	148	194	466	96	43	466	0	117	202	168
Onions	7,509	4,539	4,605	6,917	6,970	5,498	5,739	10,013	8,312	7,887	10,013	4,539	6,799	8,737	7,762
Onions (seed)	1,248	1,701	1,769	1,910	2,449	2,440	3,232	2,371	2,886	1,715	3,232	1,248	2,172	2,324	2,436
Parsley	0	0	0	64	15	38	0	20	72	77	77	0	29	56	49
Parsley (seed)	20	0	25	0	12	0	0	79	0	0	79	0	14	26	14
Parsnips	30	30	37	0	18	47	0	20	0	0	47	0	18	7	9
Peas	223	179	90	69	0	3	1	15	0	65	223	0	65	27	23
Peas (seed)	136	0	4	0	10	0	0	54	137	141	141	0	48	111	86
Peppers, hot	0	0	0	0	0	0	46	8	0	0	46	0	5	3	8
Peppers, sweet	0	0	0	0	0	0	35	12	120	179	179	0	35	104	91
Pumpkins	0	0	0	0	0	12	0	0	0	0	12	0	1	0	1
Radishes	0	0	0	3	25	26	48	149	11	27	149	0	29	62	48
Radishes (seed)	0	20	7	0	0	0	0	28	167	123	167	0	35	106	83
Rappini	259	189	110	149	170	90	305	156	184	123	305	90	174	154	167
Rhubarb	0	0	0	0	0	40	40	0	0	0	40	0	8	0	11
Rutabagas	45	40	38	45	38	57	21	40	36	0	57	0	6	25	26
Sesame (seed)	0	0	0	1	0	0	0	2	15	15	15	0		11	9
Spinach	0	0	0	0	0	0	30	0	16	48	48	0	9	21	23
Squash	1,287	1,272	971	1,078	1,112	1,358	1,471	1,286	1,416	1,009	1,471	971	1,226	1,237	1,270
Squash (seed)	0	1	0	18	31	0	0	34	0	127	127	0	21	54	45
Sweet basil	0	0	0	20	20	13	0	0	0	0	20	0	5	0	2
Swiss chard	0	0	0	1	0	0	20	1	0	6	20	0	3	2	5
Swiss chard (seed)	(0)	0	0	10	0	0	0	30	0	2	30	(0)	4	11	6
Tomatoes, fall	0	0	160	221	155	92	666	18	0	0	666	0	131	6	115
Tomatoes, spring	5,736	3,621	4,195	3,162	3,060	1,621	2,767	3,053	2,822	4,604	5,736	1,621	3,464	3,493	3,250
Tomatoes (seed)	132	0	0	0	0	0	0	0	0	0	132	0	13	0	0
Turnips	62	102	75	127	108	408	150	205	105	0	408	0	134	103	135
Vegetables, mixed	212	232	43	12	10	18	121	4	402	687	687	4	174	364	327
Vegetables, mixed (seed)	20	0	11	19	80	2	37	35	0	249	249	0	45	95	88
Waterlilies	16	16	16	16	16	18	18	17	16	16	18	16	17	16	17
Subtotal	83,476	79,480	74,574	84,715	88,854	87,343	85,155	88,469	101,141	88,258	101,141	74,574	86,147	92,623	90,838
Field Crops															
Alfalfa	125,916	133,729	139,828	141,261	148,774	148,510	136,245	160,337	162,674	171,833	171,833	125,916	146,911	164,948	159,303
Alfalfa (seed)	497	585	1,209	1,839	2,666	1,770	1,994	661	2,129	3,581	3,581	497	1,693	2,124	2,238
Alicia grass	2,900	1,961	821	965	325	168	62	52	50	14	2,900	14	732	39	56
Barley	3,481	3,585	6,761	7,735	4,098	1,895	382	232	259	259	7,735	232	2,869	250	471
Bermuda grass	2,158	2,344	3,047	2,351	2,215	2,315	3,745	3,684	2,816	2,786	3,745	2,158	2,746	3,095	3,045
Bermuda grass (seed)	1,046	1,362	1,349	2,837	4,939	5,019	5,929	7,849	16,428	13,175	16,428	1,046	5,993	12,484	10,909
Clover	0	0	0	18	0	0	20	20	150	150	150	0	36	107	88
Clover (seed)	0	35	0	0	0	70	0	349	0	90	349	0	54	146	99
Cotton	43,000	66,792	138,128	61,740	82,757	83,432	80,001	42,217	18,079	27,316	138,128	18,079	64,346	29,204	42,571
Dichondra grass	0	0	0	0	0	0	38	38	20	20	38	0	12	26	24
Field corn	0	0	0	484	0	0	0	0	294	388	484	0	117	227	189
Flax	145	3	0	0	0	0	0	0	0	0	145	0	15	0	0
Grass, mixed	0	3	5	652	845	157	204	276	30	11	845	0	218	106	111
Oats	275	148	780	182	511	271	39	717	274	464	780	39	366	485	376
Rape	0	0	0	0	0	0	0	0	267	0	267	0	27	89	65
Rye grass	8,766	6,978	5,571	8,294	2,438	1,100	2,332	4,892	2,540	6,717	8,766	1,100	4,963	4,716	4,027

Table 7-2 (Contd)

	1975	1976	1977	1978	1979	1980	1981	1982	1983[a]	1984	Max	Min	Average 10-yr	Average 3-yr	Average 5-yr wtd
Field Crops (Contd)															
Rye grass (seed)	203	22	0	0	0	0	0	188	185	86	203	0	68	153	105
Safflower	170	(0)	0	70	0	0	109	0	0	0	170	(0)	35	0	17
Sali cornia	0	0	0	0	0	0	0	0	10	0	10	0	1	3	2
Sesbania	221	4	0	150	0	74	0	0	75	75	221	0	60	50	50
Sesbania (seed)	0	0	0	0	0	0	0	38	0	0	38	0	4	13	7
Sorghum grain	24,271	16,961	7,164	15,155	8,497	3,807	2,300	2,335	1,616	1,572	24,271	1,572	8,368	1,841	2,103
Sorghum silage	560	860	465	444	510	222	775	582	552	861	861	222	583	665	645
Soy beans	0	0	81	3,342	3,092	38	145	181	0	5	3,342	0	688	62	61
Spirulina algae	0	0	0	0	0	0	0	0	12	32	32	0	4	15	13
Sudan grass	13,047	26,155	6,566	11,761	23,732	20,587	22,122	8,013	10,410	24,311	26,155	6,566	16,670	14,245	17,195
Sudan grass (seed)	0	0	0	75	0	0	0	0	228	115	228	0	42	114	90
Sugar beets	71,425	73,813	59,789	36,459	47,784	36,861	43,921	37,607	39,525	38,102	73,813	36,459	48,529	38,411	39,088
Triticale grain	0	0	0	0	0	0	55	58	0	0	58	0	11	19	19
Wheat	155,575	146,744	67,503	135,488	99,952	142,168	164,097	175,047	99,507	97,043	175,047	67,503	128,312	123,866	127,452
Subtotal	453,656	482,084	439,067	431,302	433,135	448,464	464,516	445,372	358,131	389,006	482,084	358,131	434,473	397,503	410,417
Permanent Crops															
Apricots	22	0	0	0	0	0	0	0	0	0	22	0	2	0	0
Artichokes	0	0	0	5	0	0	0	0	0	0	5	0	1	0	0
Asparagus	4,426	4,423	3,719	3,565	3,473	3,308	2,568	2,459	2,992	3,541	4,426	2,459	3,447	2,997	3,036
Citrus															
Grapefruit	600	546	442	368	295	295	294	444	464	353	600	294	410	420	380
Lemons	968	697	660	765	777	776	776	671	710	1,045	1,045	660	785	809	822
Mixed	292	287	219	220	220	176	191	191	390	203	390	176	239	261	241
Oranges	409	401	380	354	334	334	369	353	356	355	409	334	365	355	354
Tangerines	256	181	186	96	79	77	75	75	113	51	256	51	119	80	77
Dates	76	86	74	69	62	53	53	53	132	103	132	53	76	96	87
Duck ponds (feed)	6,809	7,106	7,635	7,243	7,178	7,768	8,064	8,169	12,908	8,866	12,908	6,809	8,175	9,981	9,465
Fish farms	425	448	537	529	529	624	684	754	1,196	784	1,196	425	651	911	844
Fruit, mixed	100	93	86	30	32	15	16	21	21	3	100	3	42	15	14
Grapes	0	0	0	0	0	0	0	0	30	30	30	0	6	20	16
Guar beans	0	0	0	0	0	0	299	1,892	0	0	1,892	0	219	631	389
Jojoba	0	0	2	2	2	2	508	3,062	3,005	3,005	3,062	0	959	3,024	2,273
Nursery/ornamental shrubs	8	10	9	7	7	9	5	5	0	0	10	0	6	2	3
Palms	0	0	0	1	1	4	9	11	13	9	13	0	5	11	10
Pasture, permanent	997	1,802	729	277	457	300	312	386	449	473	1,802	277	618	436	406
Peaches	35	0	0	21	73	21	24	24	40	38	73	0	28	34	32
Pecans	47	46	46	43	43	40	32	32	40	33	47	32	40	35	35
Subtotal	15,470	16,126	14,724	13,595	13,562	13,802	14,279	18,602	22,859	18,892	22,859	13,562	16,191	20,118	18,485
Total acres of crops	552,602	577,690	528,365	529,612	535,551	549,609	563,950	552,443	482,131	496,156	577,690	482,131	536,811	510,243	519,741
Total (rounded)	552,600	577,700	528,400	529,600	535,600	549,600	564,000	552,400	482,100	496,200	577,700	482,100	536,800	510,200	519,700

Note: Alfalfa acreages reduced by factor of 0.793 per DWR, 1981.
[a]IID garden crop acreage reported for 1983, modified per Imperial Valley Agricultural Commissioners crop acreage records.
Source: IID Water Reports, 1975-1984.

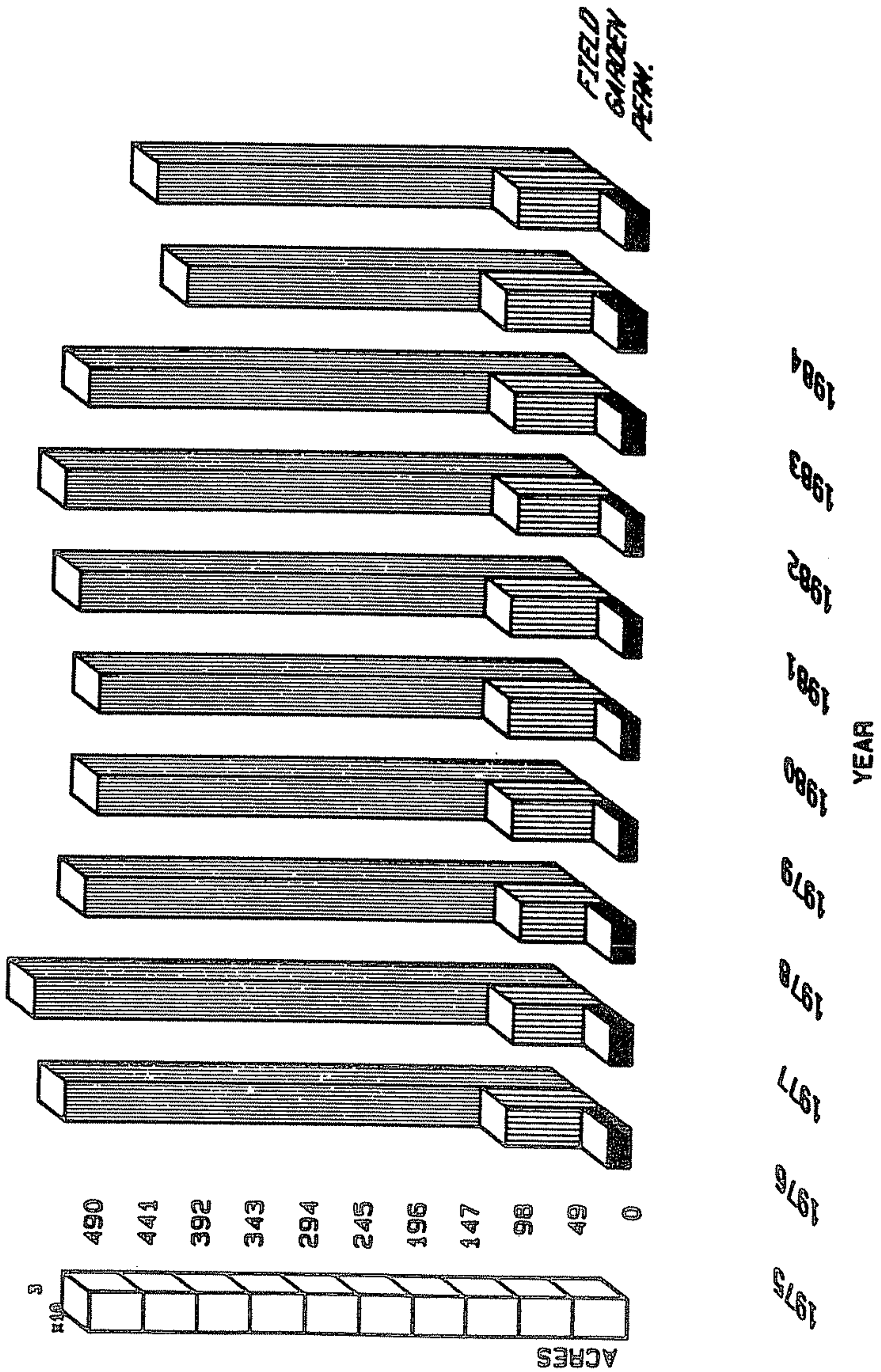

Figure 7-1 - Comparison of Crop Categories

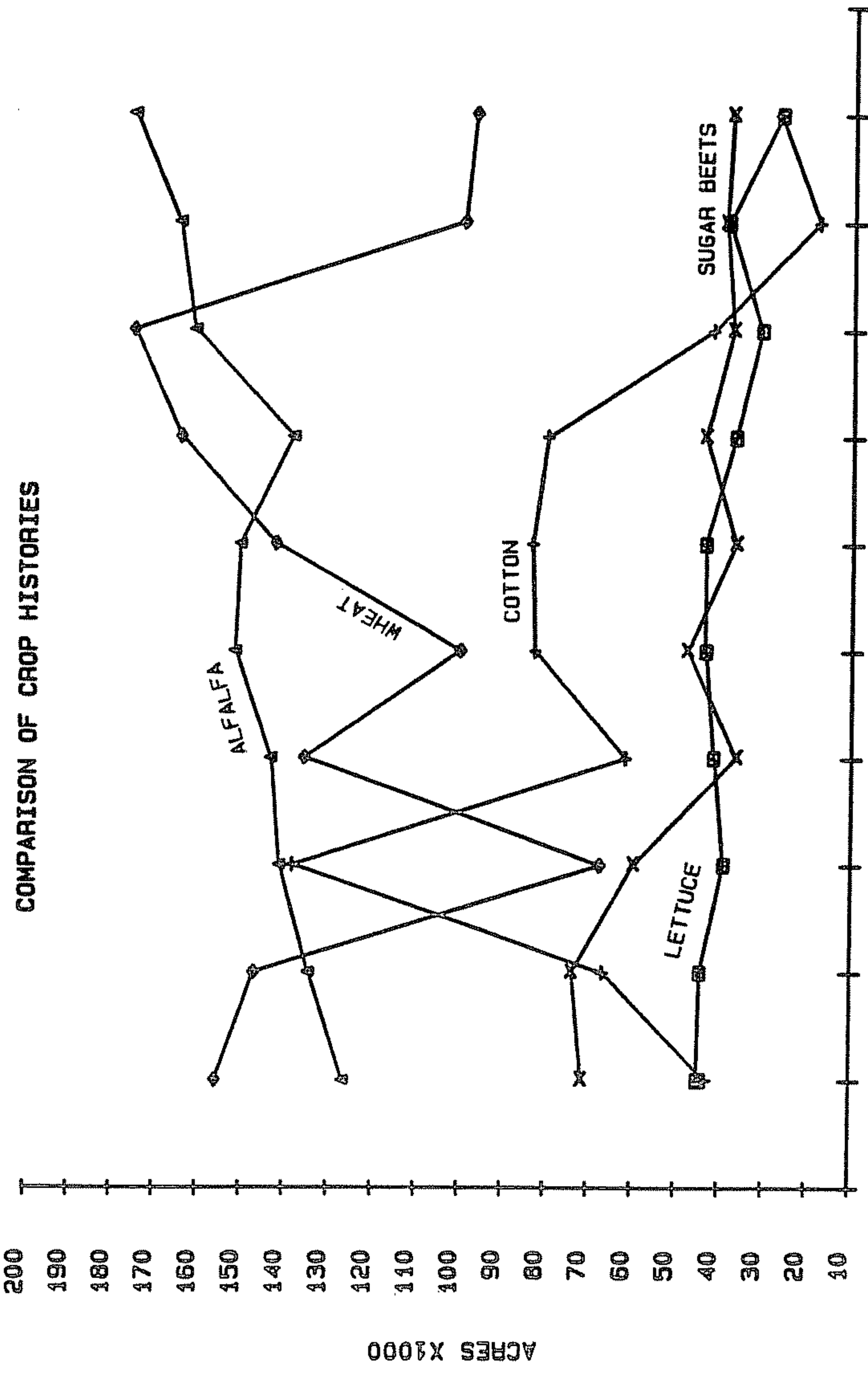

Figure 7-2 - Historical Acreage of Major Crops

Table 7-3 - Summary of Acreage Per Crop Category

	1975	1976	1977	1978	1979	1980	1981	1982	1983[a]	1984	Max	Min	Average 10-yr	Average 3-yr	Average 5-yr wtd
Garden Crops															
Broccoli	790	1,317	1,860	2,432	2,800	2,443	2,501	2,346	5,452	5,308	5,452	790	2,725	4,369	4,032
Carrots	6,010	7,642	4,429	6,598	9,256	7,684	6,605	9,135	10,112	10,089	10,112	4,429	7,756	9,779	9,102
Lettuce	45,143	44,500	39,256	41,643	43,729	44,363	37,242	31,163	38,890	27,189	45,143	27,189	39,312	32,414	34,353
Cantaloupes	7,604	9,174	10,494	13,124	10,427	11,121	14,632	14,064	19,240	5,483	19,240	7,604	12,536	16,262	15,478
Watermelons	2,472	1,984	3,166	1,037	3,136	3,292	3,987	5,379	5,172	4,896	5,379	1,037	3,452	5,149	4,719
Other melons	1,265	1,110	1,320	2,713	1,974	2,638	2,804	4,688	3,188	4,268	4,688	1,110	2,597	4,048	3,663
Onions	8,757	6,240	6,374	8,827	9,419	7,938	8,971	12,384	11,198	9,602	12,384	6,240	8,971	11,061	10,197
Squash	1,287	1,273	971	1,096	1,143	1,358	1,471	1,320	1,416	1,136	1,471	971	1,247	1,291	1,315
Tomatoes	5,868	3,621	4,355	3,383	3,215	1,713	3,433	3,071	2,822	4,604	5,868	1,713	3,609	3,499	3,365
Vegetables (misc)	4,280	2,619	2,349	3,862	3,755	4,793	3,509	4,919	3,651	5,683	5,683	2,349	3,942	4,751	4,614
Subtotal	83,476	79,480	74,574	84,715	88,854	87,343	85,155	88,469	101,141	88,258	101,141	74,574	86,147	92,623	90,838
Field Crops															
Alfalfa	126,413	134,314	141,037	143,100	151,440	150,280	138,240	160,997	164,804	175,414	175,414	126,413	148,604	167,072	161,542
Barley	3,481	3,585	6,761	7,735	4,098	1,895	382	232	259	259	7,735	232	2,869	250	471
Bermuda grass	3,204	3,706	4,396	5,188	7,154	7,334	9,674	11,533	19,244	15,961	19,244	3,204	8,739	15,579	13,954
Cotton	43,000	66,792	138,128	61,740	82,757	83,432	80,001	42,217	18,079	27,316	138,128	18,079	64,346	29,204	42,571
Rye grass	8,969	7,000	5,571	8,294	2,438	1,100	2,332	5,080	2,725	6,803	8,969	1,100	5,031	4,869	4,132
Sorghum	24,831	17,821	7,629	15,599	9,007	4,029	3,075	2,917	2,168	2,433	24,831	2,168	8,951	2,506	2,747
Sudan grass	13,047	26,155	6,566	11,836	23,732	20,587	22,122	8,013	10,638	24,426	26,155	6,566	16,712	14,359	17,285
Sugar beets	71,425	73,813	59,789	36,459	47,784	36,861	43,921	37,607	39,525	38,102	73,813	36,459	48,529	38,411	39,088
Wheat	155,575	146,744	67,503	135,488	99,952	142,168	164,097	175,047	99,507	97,043	175,047	67,503	128,312	123,866	127,452
Miscellaneous	3,711	2,154	1,687	5,863	4,773	778	672	1,729	1,182	1,249	5,863	672	2,380	1,387	1,176
Subtotal	453,656	482,084	439,067	431,302	433,135	448,464	464,516	445,372	358,131	389,006	482,084	358,131	434,473	397,503	410,417
Permanent Crops															
Asparagus	4,426	4,423	3,719	3,565	3,473	3,308	2,568	2,459	2,992	3,541	4,426	2,459	3,447	2,997	3,036
Citrus fruits	2,525	2,112	1,887	1,803	1,705	1,658	1,705	1,734	2,033	2,007	2,525	1,658	1,917	1,925	1,876
Duck ponds (feed)	6,809	7,106	7,635	7,243	7,178	7,768	8,064	8,169	12,908	8,866	12,908	6,809	8,175	9,981	9,465
Jojoba	0	0	2	2	2	2	508	3,062	3,005	3,005	3,062	0	959	3,024	2,273
Trees and vines	212	149	141	101	155	85	376	1,974	131	104	1,974	85	343	736	489
Miscellaneous	1,498	2,336	1,340	881	1,049	981	1,058	1,204	1,790	1,369	2,336	881	1,351	1,454	1,347
Subtotal	15,470	16,126	14,724	13,595	13,562	13,802	14,279	18,602	22,859	18,892	22,859	13,562	16,191	20,118	18,485
Total acres of crops	552,602	577,690	528,365	529,612	535,551	549,609	563,950	552,443	482,131	496,156	577,690	482,131	536,811	510,243	519,741
Total (rounded)	552,600	577,700	528,400	529,600	535,600	549,600	564,000	552,400	482,100	496,200	577,700	482,100	536,800	510,200	519,700

Note: Alfalfa acreage reduced by factor of 0.793 per DWR, 1981.
[a]IID garden crop acreage reported for 1983, modified per Imperial Valley Agricultural Commissioners crop acreage records.
Source: IID Water Reports, 1975-1984.

7.1.2 DEMAND VARIATIONS

The baseline demand just discussed represents a water requirement of what can be expected as a normal condition. It is not precisely an average; however, it will be treated as such to determine reasonable values for the "planning maximum" and "planning minimum" requirements. In other words, the probable deviations from a hypothetic mean value of demand will be applied to the baseline demand to establish reasonable upper and lower limits of demand for planning purposes.

The methodology used to arrive at these limits in the immediate future consisted of three steps:

(1) Statistical analysis of past variations in demand were conducted to establish standard deviation for application to projections of agricultural demand. This procedure was also applied to the projections of operational discharge.

(2) Pan evaporation data was analyzed to determine the maximum and minimum values of system evaporation losses.

(3) Near-term growth trends and projections made by local planning agencies were reviewed to establish the maximum and minimum values of industrial, municipal, and other beneficial uses.

The seepage losses were assumed to remain constant with no deviation from the baseline case for maximum or minimum conditions.

In the methodology just described, step 1 merits further explanation. The statistical analysis used the period 1954 to 1984 as a data base. The IID's inflow at Drop No. 1 during the base period was analyzed to determine:

(1) Type of distribution exhibited (i.e., normal, Pearson Type III, etc.)
(2) Standard deviation

It was deduced that the distribution was normal (an approximation close enough for planning) and that one standard deviation was approximately 5.5% of the mean. Using standard statistical tables, the following probabilities were calculated:

Probability that Demand is in Range	Range
90%	±9.1% of mean
95%	±10.8% of mean
99%	±14.2% of mean

The planning maximums and minimums were calculated, based on this statistical analysis. The 90% probability was selected as the most desirable. This decision was based on economics. The difference between the 90% and 99% probabilities translates to approximately 100,000 AF/year of water that would have to be available every year and, thus, would not be available for transfer. If the 99% range is used as a planning criterion, the full amount of this excess 100,000 AF/year would only be needed once every hundred years, and the revenue loss would have a present worth (over 40 years) of about $90 million. In contrast, the cost of providing a strategic groundwater reserve to meet demand beyond the 90% confidence level would be much less. The topic of such a reserve is discussed in greater detail in Chapter 13; however, the evidence in this analysis clearly demonstrates that a 90% confidence level is more economically effective than higher levels.

The planning maximum and minimum demands were, therefore, calculated by multiplying the baseline demand by a factor of 0.091 and by adding or subtracting the result from the baseline to arrive at the planning envelope extremes.

7.1.3 DISTRIBUTION SYSTEM CONSTRAINT ON MAXIMUM DEMAND

To establish the extremes of demand, the preceding analysis has been conducted with no consideration given to the constraint on water use of the delivery system's capacity. Therefore, an evaluation of this factor was made to determine if maximum annual water use in the IID has an upper limit governed by the capacity of the All-American Canal. The rated capacity of the canal is 6,811 ft^3/sec immediately upstream of the East Highline turnout, which, if continuously delivered, would yield a total of over 4,900,000 AF/year. However, this annual volume cannot be achieved because of the seasonal variations in demand. Figure 7-3 presents a typical schematic example of flow into the IID throughout the year.

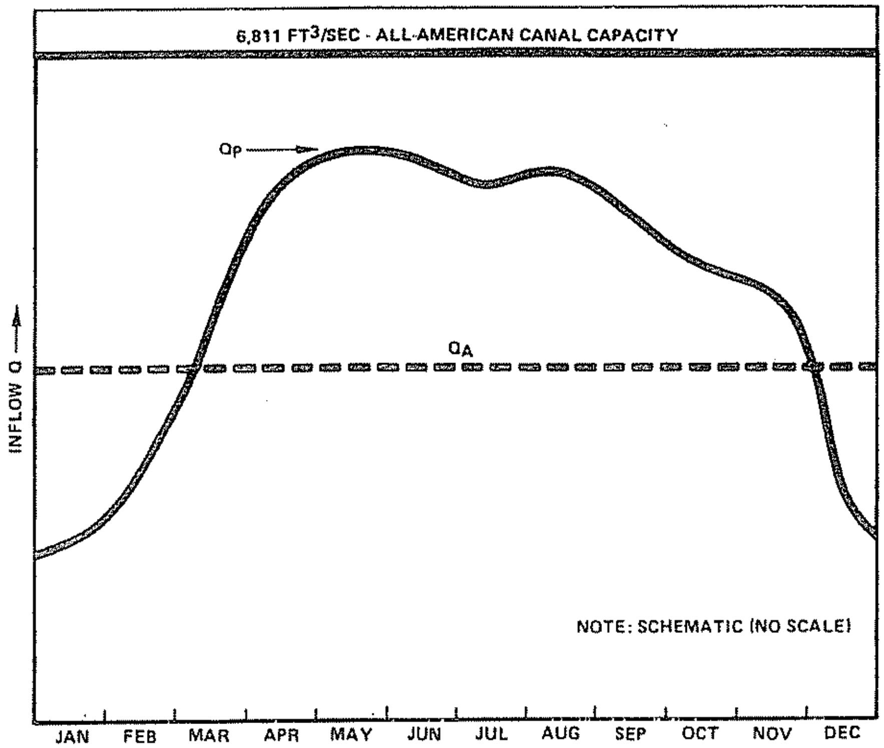

Figure 7-3 - Typical Annual Variation of Inflow to IID from All-American Canal (Parsons, 1985)

Based on a review of the records, a nominal value of the ratio of peak flow to average annual flow is:

$$\frac{Q_P}{Q_A} = \text{approximately } 1.6 \text{ (for normal conditions)}$$

This ratio tends to decrease as Q_A increases. For example, in 1953 when the IID's annual inflow was the greatest (3,353,244 AF at Drop No. 1), the ratio was:

$$\frac{Q_P}{Q_A} = \frac{6,484 \text{ ft}^3/\text{sec}}{4,632 \text{ ft}^3/\text{sec}} = 1.4$$

It should be noted that the peak flow of 6,484 ft^3/sec was over 95% of the canal's design capacity. If this flow had continued unchanged for 1 year, the annual inflow volume would have been almost 4.7 million AF. However, even under maximum demand conditions, there will be seasonal variation. If it is assumed that:

(1) $\frac{Q_P}{Q_A} = 1.3$ represents a theoretical maximum consistent with performance history

and,

(2) $Q_P = 6,811 \text{ ft}^3/\text{sec} = 4.93$ million AF/year

then, the value of Q_A is:

$$Q_A = \frac{Q_P}{1.3} = 3.8 \text{ million AF/year}$$

Therefore, an annual flow of 3.8 million AF approximates the ultimate maximum amount of water deliverable under current conditions.

However, considering the limitations of the Seven-Party Agreement, it is doubtful that even this amount would ever be available for use by the IID.

7.2 TRANSMISSION AND DISTRIBUTION SYSTEM LOSSES

The IID diverts water from the Colorado River at Imperial Dam. From this point until water is delivered at the farmer's head gates, there are losses that are considered transmission and distribution system losses. These losses occur from seepage, evaporation, operational discharge, and other miscellaneous losses. Table 7-4 summarizes the transmission and distribution system losses from Imperial Dam to Drop No. 4 and for the main canals and laterals below Drop No. 4. By far the greatest quantity of loss occurs from seepage. Although it is not possible to obtain exact quantities of seepage, estimates have been made by the USBR and the DWR of the quantity of seepage. Using that information contained in studies by those agencies and evaluation of the overall hydrologic balance in the District discussed in Chapter 5, a preliminary quantity of seepage is set forth herein. Further refinement can

Table 7-4 - Transmission and Distribution System Losses

Component	Water Loss (AF/year) Baseline	Maximum	Minimum
Main Canals and Laterals (below Drop No. 4)			
Seepage	175,000	175,000	175,000
Evaporation[a]	19,000	21,000	18,000
Operational discharges	88,000	96,000	80,000
Subtotal	282,000	292,000	273,000
Imperial Dam to Drop No. 4			
All-American Canal seepage	155,000	155,000	155,000
Evaporation	7,600	8,300	7,100
Ordered but delivered to Mexico in excess of treaty	14,000	42,000	200
Subtotal	176,600	205,300	162,300
Total	458,600	497,300	435,300

[a]Includes evaporation from four existing reservoirs of 1,000 AF/year.
Source: Parsons, 1985.

only be obtained by additional measurement and study. Although of a lesser quantity than seepage, the discharge from canals for operational purposes is largely unmeasured. In recent years, recording gauges have been placed at some of the discharge points, and some quantification of this amount can be made. Additional losses occur from evaporation from canal and reservoir surfaces.

7.2.1 SEEPAGE LOSSES

In 1981, based on the District's records and on previous reports by others, the DWR estimated that seepage from main canals and laterals other than the All-American Canal was 184,000 AF/year. This figure would indicate a total amount of canal seepage downstream of Drop No. 1 of 229,000 AF. The USBR (Special Report, July 1984) reported canal seepage downstream from Drop No. 1 to be 305,000 AF. This revision is of a prior estimate of 232,000 AF of canal seepage downstream of Drop No. 1 (USBR, 1981b). Thus, the estimated rate of seepage downstream of Drop No. 1 (generally for the period of the late 1970s) ranged from 229,000 AF to 305,000 AF/year. Each report expressed concern over the accuracy of the seepage estimates, and in reviewing these references, it was determined that the lower values fit the water balance estimate better. A historical accounting of the distribution of losses in the All-American Canal reported by the IID (IID Water Reports, 1975-1984) is presented in Table 7-5. These figures include evaporation and seepage losses from Imperial Dam to the Westside Main Canal. Losses upstream of Drop No. 1 include amounts of water allocated to the Coachella Valley Water District, and a portion of the seepage below Drop No. 1 is picked up in side canals and returned to the system. Some seepage east of Pilot Knob returns to the Colorado River as subsurface flow.

The determination of the amount of canal seepage is extremely difficult, and refinement of the quantities requires additional work. The IID set forth a program to monitor and determine the amount of canal seepage more accurately (IID Water Conservation Plan, 1985). In general, this program included the preparation of a map showing all unlined sections of laterals superimposed on a soils map. Each unlined lateral will be inventoried and rated by expected seepage characteristics. Several seepage measurements would be made each year using ponding studies. An annual memorandum report is to be prepared in which relative data, test results, and an annual estimate of seepage will be reported.

The District has a very aggressive canal lining program. Historically, canals were lined based on cooperative agreements between the District and the adjacent landowner. Under these agreements, the landowner paid for a portion of the cost of the lining. This was a beneficial program because those landowners who were interested in participating financially were usually those who were interested in the increased land available from canal lining and whose land experienced waterlog damage and increased maintenance due to seepage on adjacent land. There has been a recent decline in this program of joint cooperation and participation primarily because many landowners found that they could not continue to financially contribute to the program and that many of the areas of immediate concern had been previously lined. Because of this decline, the District has recently assumed full responsibility for prioratizing the canal linings. The District has prioratized the lining of laterals based on:

(1) USBR study list (USBR, 1984a)

(2) District and landowners maintenance problems (mainly hydrilla)

(3) Filling in gaps between lined portions

(4) Canal reaches reported by Division Superintendents to have high seepage

The District has installed canal seepage collection facilities along the All-American Canal between Drop No. 1 and the East Highline Check, the All-

Table 7-5 - Losses in All-American Canal[a]

Reach	Unlined Length (miles)	Estimated Seepage and Evaporation Losses (1,000 AF/year) 1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	10-year Average
Imperial Dam (Sta 37 + 90) to Pilot Knob[b]	20.10	81	95	103	75	84	111	77	66	144	-7	82.9
Pilot Knob to Drop No. 1	15.37	54	58	29	52	49	57	82	59	106	46	59.2
Drop No. 1 to East Highline check	20.29	59	33	22	24	8	34	23	19	28	32	28.2
East Highline to Westside Main Canal	21.32	9	20	18	23	12	29	21	17	28	29	20.6
Total	77.08	203	206	172	174	153	231	203	161	306	100	190.9

[a]From IID records.
[b]Water losses upstream of Pilot Knob return to Colorado River as groundwater seepage.
Source: IID Water Reports, 1975-1984.

American Canal downstream of the East Highline Check, and the East Highline. The estimated amount of water conserved in the canal seepage recovery systems is:

Location	Estimated Annual Saving (AF)
All-American Canal from Drop No. 1 to East Highline Check	5,000 (est)
All-American Canal Downstream to East Highline Check	3,000 (est)
East Highline	17,000
Total	25,000

The amount of water that can be salvaged by lining canals is less than the gross amount of seepage:

(1) The amount picked up in current seepage collection facilities already represents an amount of water conserved. Consideration could also be given to constructing additional canal seepage collection facilities, especially along the East Highline Canal.

(2) There are losses in lined canals.

(3) There are canals with very low infiltration rates or canals that are infrequently used where lining is uneconomical.

Based on current interpretations, the canal seepage downstream of Drop No. 1 is approximately 220,000 AF as of 1984. This is equivalent to about 200,000 AF of seepage downstream of Drop No. 4. In the water balance analysis presented in Chapter 5, a seepage rate of 200,000 AF/year was used for 1984. The 1985 value for seepage below Drop No. 4 is estimated at 200,000 AF/year, based on the District's continuing program of canal lining. The net seepage below Drop No. 4 is reduced somewhat by seepage recovery facilities, which return approximately 25,000 AF/year to the canals. The water loss due to seepage from below Drop No. 4, less the seepage recovery estimate, is presented in Table 7-4. The seepage estimate from Imperial Dam to Drop No. 4 is based on historical losses reported by the IID, previous estimates, and the District's current canal lining program. The estimates of seepage losses for the maximum and minimum water loss scenarios remain unchanged from the baseline estimate because the maximum and minimum projections assume that no additional water conservation measures are taken beyond the present levels, i.e., canal lining.

7.2.2 EVAPORATION LOSSES

Evaporation from water surfaces in the District's transmission and delivery system represents less than 5% of the total transmission losses. Estimates of the losses for the All-American Canal from Imperial Dam to Drop No. 4 and the canals and laterals below Drop No. 4 are presented in Table 7-4. Losses from water surfaces in canals and laterals were based on the maximum height of water in canals, design dimensions of structures, known lengths of canals, and an assumed evaporation rate of 6 ft/year. The evaporation from the District's four existing reservoirs was also considered in estimating the total water loss. Evaporation from reservoirs estimated at 1,000 AF/year is minimal when compared with total evaporation water losses.

Because variations in evaporation losses occur primarily from changes in temperature and secondarily from such factors as wind, cloud cover, and humidity, the estimates of maximum and minimum evaporative losses were made on the basis of pan evaporation data. The average, maximum, and minimum pan evaporation was determined from reviewing historical pan evaporation data for the period 1960 through 1984, recorded at the U.S. Agricultural Research Station in Brawley, California (USDA, 1984). The ratio of the historical maximum pan evaporation (approximately 125 in.) to the 24-year period average of approximately 115 in. was applied to the baseline estimate to determine the maximum evaporation loss; whereas, the ratio of the reported historical minimum pan evaporation to the 24-year average was used to determine the evaporation loss for the minimum scenario.

7.2.3 OPERATIONAL DISCHARGE LOSSES

There are 241 locations where water from the canals can be discharged for operational reasons. The amount of water discharged is generally a small percentage of diversions and represents the mismatch between water released to a lateral canal, seepage, and actual deliveries to farmers. In addition, water is discharged from canals during periodic maintenance activities. An example of this is the drying of canals for cleaning purposes and for weed and hydrilla control.

Until recently, very few measurements were made of the discharge from canals. The number of measurements was increased in 1981. Based on this data, it is estimated that discharge losses from main canals and laterals below Drop No. 4 for operational reasons are currently at a level of approximately 88,000 AF/year (see Table 5-4). Because operational discharges are a function of the volume of water delivered to users, the estimates of maximum and minimum discharge losses from the main canals and laterals below Drop No. 4 were determined by adjusting the baseline discharge loss estimate in relation to the applied water for agricultural use. The baseline value of 88,000 AF was multiplied by the ratio of the maximum agricultural water use to the baseline agricultural water use to estimate the maximum discharge loss. The minimum discharge loss of 80,000 AF was obtained by applying the ratio of the minimum agricultural water use to the baseline agricultural water use. Current baseline levels are somewhat lower than previously experienced because of the greater interest in water conservation. Thus in the 1970s, the amount of canal discharges is estimated to have averaged about 135,000 AF/year. These amounts are shown in Chapter 5.

Because of the difficulty in estimating the amount of canal discharge, the District (IID Water Conservation Plan, 1985) proposed a canal discharge monitoring program. The District plans to annually estimate the amount of canal discharge and constantly evaluate canal operations.

Operational discharges from the All-American Canal at Imperial Dam and Pilot Knob sometimes result because of changes in water demand from the time water is ordered from Hoover Dam to the time it arrives 3 days later at Imperial Dam. Water ordered by IID and discharged to the Colorado River in excess of Mexican water requirements was estimated at an average of 14,000 AF/year, based on data recorded during 1966 to 1982 (USBR, 1984). The range of discharges during this period was used to establish values for maximum and minimum water loss scenarios. Operational discharges for baseline, maximum, and minimum conditions are presented in Table 7-4.

Losses from the canal system as described above constitute by far the majority of any loss. Canal losses do occur during infrequent times when rainstorms sweep through the Imperial Valley. These losses occur partially because of the increase in rain water falling directly on the canal and flood waters breaking into canals, but the losses are also due to the effect that severe rainstorms have on causing a cessation of irrigation activities, with the result that the District has no place to put its water that is already moving downward through the irrigation system. Occasional breaks in the canal system also contribute minor amounts to miscellaneous system losses.

7.3 AGRICULTURAL WATER REQUIREMENTS

The current water requirements for agricultural water use represent by far the greatest water use within the IID, and they have been divided for this study into four major categories:

(1) Crop consumptive use
(2) Leaching
(3) Tailwater
(4) Miscellaneous on-farm water uses

Water required for crop consumptive use is calculated on the basis of the historical acreage per crop and by the use of accepted unit values for variables needed to determine the current water requirements. A determination of tailwater is based on the water balance analysis presented in Chapter 5. Water required for leaching is estimated through an evaluation of available salinity and quantity measurements of water supply, as well as consumptive use and an analysis of drainage characteristics. Estimates of on-farm seepage and evaporation were used to determine the miscellaneous on-farm water uses.

7.3.1 CROP CONSUMPTIVE USE

Crop consumptive use is defined as the sum of water used by plants in transpiration and growth (stored in plant tissue) and evaporation from adjacent soil and water surfaces during and shortly after irrigation. It is expressed in acre-feet/acre per year.

Crop evapotranspiration, effective precipitation, and crop acreage constitute the major components in determining the consumptive use of applied water for each crop category. In Table 7-6, crop consumptive use of applied water is computed using crop evapotranspiration unit values that have been generally accepted for the Imperial Valley agricultural area (Blaney and Criddle, 1962;

Table 7-6 - Crop Consumptive Use

Crops	Area[a] (acres)	ET[b] (ft)	EP[c] (ft)	CU of AW[d] (AF)
Garden Crops				
Broccoli	4,032	1.7	0.06	6,612
Carrots	9,102	1.3	0.09	11,029
Lettuce	34,353	1.4	0.06	46,148
Cantaloupes	15,478	2.3	0.09	34,271
Watermelons	4,719	2.3	0.11	10,315
Other melons	3,663	2.3	0.07	8,153
Onions	10,197	1.9	0.13	18,074
Squash	1,315	1.7	0.12	2,076
Tomatoes	3,365	2.3	0.07	7,510
Vegetables (misc)	4,614	1.7	0.08	7,459
Subtotal	90,838			151,646
Field Crops				
Alfalfa	161,542	5.4	0.22	839,749
Barley	471	1.8	0.15	777
Bermuda grass	13,954	3.6	0.13	48,490
Cotton	42,571	3.6	0.15	146,764
Rye grass	4,132	2.5	0.13	9,814
Sorghum	2,747	2.5	0.06	6,712
Sudan grass	17,285	2.5	0.13	41,052
Sugar beets	39,088	3.7	0.21	136,482
Wheat	127,452	2.1	0.15	248,213
Miscellaneous	1,175	2.5	0.15	2,758
Subtotal	410,417			1,480,811
Permanent Crops				
Asparagus	3,036	4.2	0.08	12,503
Citrus fruits	1,876	3.8	0.22	6,719
Duck ponds (feed)	9,465	3.0	0.00	28,395
Jojoba	2,273	3.8	0.22	8,141
Trees and vines	489	3.8	0.22	1,751
Miscellaneous	1,347	4.2	0.22	5,363
Subtotal	18,486			62,873
Total acres of crops	519,741			1,695,330
Total (rounded)	519,700			1,695,000

[a] 5-year weighted average of categorized crop acreage within the IID as discussed in subsection 7.1.1 and calculated in Table 7-3.
[b] Evapotranspiration unit values.
[c] Effective precipitation, based on 90% of 71-year average monthly rainfall conditions (Appendix Table E-3) and determined for each crop using the crop calendar published by the IID and monthly EP values.
[d] Consumptive use of applied water: Area x (ET-EP).
Source: Blaney and Criddle, 1962, Ua, 1968; Kaddah and Rhodes, 1976; Donovan and Meek, 1983; DWR, 1983c; Parsons, 1985.

UA, 1968; Kaddah and Rhodes, 1976; Donovan and Meek, 1983; DWR, 1983c). Alfalfa is the largest single crop grown in the Imperial Valley, approximately 30% of the total acres in crops, and the selection of a representative unit value for evaportranspiration is significant in the estimated consumptive use within the IID. A unit value of consumptive use for alfalfa of 5.4 AF/acre was adopted for this study, based on an evaluation of irrigation scheduling, cultural practices, weather and soil conditions, as well as the testimony of Norman A. Macgillivray, DWR, before the State Water Resources Control Board (DWR, 1983c), which summarized various evapotranspiration studies conducted in the Imperial Valley.

It is recognized that the adopted value is less than the value of 6.0 AF/acre historically used by the District, but it is consistent with the evaluation of the total District's consumptive use derived by hydrologic balance and discussed in Chapter 5. The reason for this discrepancy is not clear, but it could be caused by weather, soil conditions, and cultural practices that limit the optimum irrigation scheduling causing occasional stress in the crop.

Baseline evapotranspiration values are adjusted by subtracting the effective precipitation to reflect rainfall contribution throughout the growing season of crops listed in Table 7-6. The effective precipitation for baseline demand conditions for each crop was based on:

(1) The 71-year average monthly rainfall values (developed from Appendix Table E-2).

(2) The IID's cropping schedule for estimating time and duration of effective rainfall per individual crop during the growing season (IID, n.d., in ES, 1980). The effective monthly precipitation for baseline rainfall conditions is presented in Appendix Table E-3.

The calculation of baseline effective precipitation assumes that 90% of the monthly rainfall is effective. The baseline evapotranspiration is adjusted by subtracting the estimated effective precipitation for each crop. These evapotranspiration values are then multiplied by crop acres under baseline conditions to yield the consumptive use of applied water.

In Chapter 5, the total crop consumptive use was computed as the closure term in the hydrologic water balance by means of subtraction. To verify the validity of these consumptive use values, the total crop consumptive use was determined annually for the period 1975-1984 by using the unit value method. In this method, the evapotranspiration unit values from Table 7-6 are applied to the annual crop acreages summarized in Table 7-3 to determine the total crop consumptive use. The total annual consumptive use of each crop category for the period 1975-1984 is presented in Appendix G, Table G-1. A discussion of the total values developed from each approach is presented in subsection 5.3.5.

7.3.2 LEACHING

The leaching requirement represents a significant portion of the on-farm agricultural water requirement. Leach water is considered a beneficial and reasonable use of water because it is essential for removing accumulated salts from the crop root zone.

In determining the total amount of water required for leaching used in this report, an extensive analysis was conducted to evaluate several methods used to compute the leaching requirement. These methods generally relate salinity of the irrigation water and saturation extract to the salinities at which crop yields will be affected. Results from these analyses were compared to previous estimates of leach water based on current irrigation practices and drainage conditions in the Imperial Valley.

The water required for leaching was calculated according to the following standard methods used in agriculture by various researchers:

(1) FAO Method for Surface Irrigation Applications (FAO, 1976)
(2) Handbook 60 Method (USDA, 1954)

Both the FAO and the Handbook 60 methods use the electrical conductivity of the irrigation water and of the soil saturation extract as variables to determine the concentration effect of consumptive use on soil salinity.

A reduction in crop yields at various salinity levels has been determined in field and laboratory trials by various researchers. A recent study by G.J. Hoffman (Hoffman, 1985), in which several theoretical methods of computing a leaching requirement were compared to determinations from field measurements, indicated that mathematical models developed to predict leaching requirements at various levels of yield reduction have a correlation coefficient of less than 0.7, indicating, as a minimum, that neither the FAO nor Handbook 60 method could be used directly with much confidence.

The total amount of leaching water developed in Chapter 5 was tested against the theoretical amount of leaching developed by the various methods. Assuming adequate leaching to limit yield reduction to 10%, the amount of leach water derived theoretically ranged from about 120,000 AF to 800,000 AF/year. Recognizing that crop yields within the District are reasonable and do not appear to be significantly reduced because of inadequate leaching, the leach water requirement adopted for this report is 280,000 AF/year as derived in Chapter 5.

7.3.3 TAILWATER

Tailwater is defined as the surface runoff leaching at the end of a farm field during irrigation. The determination of the tailwater quantity for baseline conditions is based on historical evaluations of previous tailwater estimates from the water balance analysis in Chapter 5, as well as a review of current irrigation practices in the Imperial Valley. A 5-year weighted average of tailwater estimates (presented in Table 5-6) was adopted as the baseline tailwater use. The tailwater component was estimated at 270,000 AF/year, representing approximately 12% of the total agricultural water requirement.

7.3.4 MISCELLANEOUS ON-FARM WATER USES

The miscellaneous on-farm uses of water are defined in the on-farm baseline loss criteria (subsection 4.3.2) as relatively minor components contributing to the total agricultural water requirement. The major components contributing to miscellaneous on-farm water uses are the on-farm seepage and the evaporation losses. Other water uses include consumptive use of weeds present in and alongside of on-farm water distribution surfaces, as well as losses due to operational mishaps.

The on-farm losses consist of seepage and evaporation water loss estimates from farm head ditches, distribution tanks/basins preceding cropped areas, and tailwater collection ditches and storage ponds. Evaporation and seepage losses were based on a total length of ditches estimated at 3,000 miles (IID Water Conservation Plan, 1985; IID Water Report, 1984) and typical ditch dimensions consisting of a 20-ft base, 1:1 side slopes, and an 18-in. average water depth.

The on-farm evaporation losses were estimated using a conservative evaporation rate of 6 ft/year. The evaporation rate was determined by using historical pan evaporation records compiled at the U.S. Agricultural Research Station located in Brawley, California (USDA, 1984). The average yearly pan evaporation over the period of 1960 to 1984 of approximately 115 in. was adjusted using a pan evaporation coefficient of 0.70. An estimate of the water loss caused by seepage of unlined ditches, based on a seepage rate of 0.5 ft/day, accounted for 75% of the miscellaneous on-farm losses.

The total water loss for baseline conditions due to evaporation and seepage from on-farm surfaces is estimated to be about 10,000 AF/year, with evaporation representing approximately 3,000 AF/year. These on-farm uses represent an insignificant water demand (less than 1% of the total agricultural water requirement) in relation to crop consumptive use, leaching, and tailwater components.

7.3.5 TOTAL AGRICULTURAL WATER REQUIREMENTS

Table 7-7 summarizes the total agricultural water requirement for the baseline maximum, and minimum demand scenarios.

Table 7-7 - Total Agricultural Water Requirements[a]

Component	Water Use (1,000 AF/year) Baseline	Maximum[b]	Minimum
Consumptive use	1,695	1,849	1,541
Leaching	280	305	255
Tailwater	270	295	245
Total	2,245	2,449	2,041

[a]Total excludes miscellaneous on-farm uses considered negligable at approximately 10,000 AF/year in relation to the total agricultural water requirement.
[b]Maximum and minimum values determined by statistical analysis.
Source: Parsons, 1985.

7.4 OTHER REQUIREMENTS

Water requirements for agricultural uses and transmission system losses have been discussed in previous sections. The remaining categories consist of municipal water use, industrial water use, and other beneficial water uses.

7.4.1 MUNICIPAL WATER USE

The IID provides wholesale water service to 10 cities and towns within the Imperial Valley. Each town diverts water from IID's canal system to its treatment facility prior to distribution for municipal uses. The annual deliveries and populations of each of these towns for the base period 1975 to 1984 are presented in Table 7-8. The three averages for these deliveries, calculated on the same basis as the agricultural crop acreages discussed in section 7.1, are shown in Table 7-9. In addition to each town's diversion, farmers in rural areas and communities also receive water directly from the canal system, treating it as necessary. The average per capita consumption for towns was used along with nonurban population estimates (Table 2-11) to determine the nonurban municipal water use for each year.

Table 7-10 is derived from several previous tables and presents the current municipal water requirement. The population totals are for the year 1985, and they were used to calculate the acre-feet of water used. The 5-year weighted gallon per capita per day averages of Table 7-9 were used to determine the baseline municipal water use. The gallons per capita per day for maximum and minimum water demands were obtained by selecting the highest and lowest values for each town from Table 7-8. The total municipal water use for baseline, maximum, and minimum conditions is presented in Table 7-10.

Table 7-8 - Annual Water Delivered and Population Totals for IID Serviced Area for 1975-1984

Town/Area	1975			1976			1977			1978			1979		
	Population	AF/yr	gpcd	Population	AF/yr	gpcd	Population	AF/yr	gpcd	Population	AF/yr	gpcd	Population	AF/yr	gpcd
Brawley	14,010	7,600	484	14,010	6,768	431	14,138	6,723	424	14,138	7,458	471	14,150	7,396	467
Calexico	13,020	4,580	314	13,020	4,422	303	13,200	3,814	258	13,341	4,638	310	13,550	4,439	292
Calipatria	2,074	953	410	2,074	898	387	2,170	974	401	2,360	1,216	460	2,510	1,478	526
El Centro	21,295	5,224	219	21,295	6,800	285	22,660	6,791	268	22,660	7,077	279	24,350	6,575	241
Heber	2,300	268	104	2,300	329	128	2,206	333	135	2,206	334	135	2,300	325	126
Holtville	4,345	1,492	307	4,345	1,365	280	4,480	1,376	274	4,480	1,475	294	4,570	1,657	324
Imperial	3,213	2,910	809	3,213	2,086	580	3,210	1,999	556	3,244	1,727	475	3,360	1,757	467
Niland	1,300	688	472	1,300	431	296	1,300	598	411	917	860	837	975	703	643
Seeley	1,000	320	286	1,000	334	298	948	327	308	948	332	313	1,010	330	292
Westmorland	1,417	887	559	1,417	1,108	698	1,440	951	590	1,550	1,112	640	1,570	1,344	764
Nonurban	17,240	6,721	348	17,585	6,737	342	17,936	6,510	324	19,464	7,762	356	18,938	7,213	340
Total/average	81,214	31,643	348	81,559	31,280	342	83,688	30,395	324	85,308	33,992	356	87,283	33,216	340
Total (rounded)	81,200	31,600		81,600	31,300		83,700	30,400		85,300	34,000		87,300	33,200	

Source: IID Water Reports, 1975-1984; Parsons, 1985.

Table 7-8 (Contd)

Town/Area	1980			1981			1982			1983			1984		
	Population	AF/yr	gpcd	Population	AF/yr	gpcd	Population	AF/yr	gpcd	Population	AF/yr	gpcd	Population	AF/yr	gpcd
Brawley	14,753	9,052	548	15,585	8,027	460	15,950	7,870	440	17,160	7,960	414	17,372	8,612	443
Calexico	14,545	4,380	269	15,099	4,798	284	15,079	5,110	303	15,838	5,110	288	16,441	5,448	296
Calipatria	2,586	1,212	418	2,655	1,220	410	2,703	1,200	396	2,706	1,337	441	2,709	1,249	412
El Centro	24,015	6,809	253	24,949	6,871	246	25,534	6,387	223	26,402	6,240	211	26,764	7,026	234
Heber	2,300	334	130	2,300	342	133	2,221	402	162	2,221	345	139	2,221	348	140
Holtville	4,355	1,600	328	4,579	1,864	363	4,570	1,563	305	4,637	1,516	292	4,656	1,695	325
Imperial	3,440	1,834	476	3,576	1,947	486	3,627	2,015	496	3,708	2,067	498	3,732	1,809	433
Niland	975	497	455	975	636	582	1,042	1,022	876	1,042	789	676	1,042	612	524
Seeley	1,010	330	292	1,010	342	302	1,058	346	292	1,058	346	292	1,058	345	291
Westmorland	1,572	1,124	638	1,619	929	512	1,720	1,001	520	1,718	1,102	573	1,776	726	365
Nonurban	19,570	7,651	349	19,075	7,116	333	20,051	7,345	327	19,479	6,830	313	20,440	7,327	320
Total/average	89,121	34,823	349	91,422	34,093	333	93,555	34,261	327	95,969	33,642	313	98,211	35,198	320
Total (rounded)	89,100	34,800		91,400	34,100		93,600	34,300		96,000	33,600		98,200	35,200	

Source: IID Water Reports, 1975-1984; Parsons, 1985.

Table 7-9 - Municipal Water Use Averages

Town/Area	10-year Average			3-year Average			5-year Weighted Average		
	Population	AF/yr	gpcd	Population	AF/yr	gpcd	Population	AF/yr	gpcd
Brawley	15,127	7,747	458	16,827	8,147	432	16,474	8,284	451
Calexico	14,313	4,674	292	15,786	5,223	295	15,614	5,077	290
Calipatria	2,455	1,174	426	2,706	1,262	416	2,684	1,253	417
El Centro	23,992	6,580	246	26,233	6,551	223	25,844	6,670	231
Heber	2,258	336	133	2,221	365	147	2,243	354	141
Holtville	4,502	1,560	309	4,621	1,592	307	4,588	1,642	320
Imperial	3,432	2,015	527	3,689	1,964	475	3,648	1,933	473
Niland	1,087	684	577	1,042	808	692	1,024	719	625
Seeley	1,010	335	296	1,058	346	292	1,045	343	293
Westmorland	1,580	1,028	586	1,738	943	486	1,703	946	499
Nonurban	18,978	7,121	335	19,990	7,167	320	19,824	7,217	325
Total/average	88,733	33,254	335	95,912	34,367	320	94,690	34,437	325
Total (rounded)	88,700	33,300		95,900	34,400		94,700	34,400	

Source: IID Water Reports, 1975-1984; Parsons, 1985.

Table 7-10 - Municipal Water Use Scenarios

Town/Area	Population	Baseline gpcd	Baseline AF/yr	Minimum gpcd	Minimum AF/yr	Maximum gpcd	Maximum AF/yr
Brawley	17,636	451	8,902	414	8,181	548	10,820
Calexico	16,928	290	5,497	258	4,891	314	5,954
Calipatria	2,683	417	1,252	387	1,162	526	1,580
El Centro	27,300	231	7,055	211	6,453	285	8,719
Heber	2,392	141	378	104	279	162	433
Holtville	4,678	320	1,675	274	1,437	363	1,904
Imperial	3,869	473	2,051	433	1,875	809	3,505
Niland	1,122	625	786	296	372	876	1,100
Seeley	1,139	293	374	286	365	313	399
Westmorland	1,851	499	1,034	365	757	764	1,585
Nonurban	20,978	325	7,640	313	7,355	356	8,366
Total/average	100,576	325	36,646	294	33,126	394	44,365
Total (rounded)	100,600		36,600		33,100		44,400

Source: Parsons, 1985.

7.4.2 INDUSTRIAL WATER USE

Excluding agriculture, industry within the Imperial Valley is minimal. One area of industry that has received significant interest in recent years, however, is the geothermal industry. Facilities currently in place within the geothermal industry include three pilot plants that use water for cooling and reinjection. The 1984 water use at these facilities amounted to 1,397 AF. The facilities and their owners are:

(1) East Mesa Geothermal (MAGMA)
(2) Brawley Geothermal (Union - SCE)
(3) Salton Sea Geothermal (Union - SCE)

The major industrial water uses outside of the urban areas are on the order of 3,000 AF/year. These industries are:

(1) Holly Sugar Corporation
(2) Simcal ammonia producers
(3) Various cotton gins and compressors
(4) Chemical and fertilizer producers
(5) Steam Turbine Electrical Generating Station

Another component of industrial water use is that used by the U.S. Naval Air Station that amounted to 748 AF/year in 1984. Table 7-11 presents water use

Table 7-11 - Industrial Water Use

Delivered Water	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Max	Min	Average 10-yr	Average 3-yr	Average 5-yr wtd
Industrial	6,162	6,776	7,225	6,888	7,790	5,382	6,531	4,526	2,470	2,417	7,790	2,417	5,617	3,155	3,796
Geothermal	4	0	0	96	416	710	947	1,091	1,627	1,397	1,627	0	629	1,448	1,246
Feedlots	8,900	10,700	10,700	11,700	13,400	11,600	10,500	10,300	11,200	11,700	13,400	8,900	11,070	10,900	11,130
U.S. Naval Air Station	500	500	580	576	554	564	566	572	663	748	748	500	582	633	646
Total	15,566	17,976	18,505	19,260	22,160	18,256	18,544	16,489	15,960	16,262	22,160	15,566	17,898	16,136	16,818
Total (rounded)	15,600	18,000	18,500	19,300	22,200	18,300	18,500	16,500	16,000	16,300	22,200	15,600	17,900	16,100	16,800

Source: Parsons, 1985

data for the various industries. Again, the three averages are calculated as discussed in section 7.1. The baseline total or 5-year weighted average was approximately 16,800 AF. The historical maximum and minimum industrial water used for the IID represented the water demand for the maximum and minimum scenarios.

7.4.3 OTHER BENEFICIAL WATER USES

The major remaining categories of beneficial water use within the IID include fish and wildlife, irrigation of schools and cemeteries, and recreational uses such as lakes, parks, and golf courses. The IID maintains a 100-acre pond in the New River bottom for wildlife habitat, and the CDFG maintains about 360 acres of fish hatcheries and 1,400 acres of waterfowl habitat. Land used for wildlife habitat and fish hatcheries in the IID is included in its reported crop acreages under the categories listed as duck ponds and fish farms (Table 7-2). Water required for these uses has been accounted for in the agricultural component of the total water requirement and will not be considered here.

The water loss through service pipes is estimated at approximately 2,000 AF/year. This estimate is based on the number and respective diameter of pipes in areas serviced by the IID. The schools, cemeteries, and golf course, as well as their annual water use and water use data for lakes, parks, etc., are presented in Table 7-12. The total beneficial water use is estimated at about 10,400 AF/year and is assumed constant for the maximum and minimum water demand scenarios because of the negligible fluctuation in the amount of water required by these facilities.

The overall water required for industrial, municipal, and other beneficial uses is summarized in Table 7-13.

7.5 TOTAL CURRENT WATER REQUIREMENTS

Table 7-14 gives the total current water requirement, which is a summary of all water use components and their respective water requirements. Baseline values reflect 5-year weighted averages in most cases; whereas, maximum and minimum water demand values reflect historical maximum and minimum for each specific category over the time period of 1975 to 1984. As Table 7-14 indicates, the agricultural component exerts definitive influence on the total current water requirements, while the municipal, industrial, and other beneficial uses require less than 3% of the total demand. Water use via transmission losses represent approximately 17% of the total requirement.

7.6 POTENTIAL WATER CONSERVATION

Based on the work presented in Chapters 4, 5, and 7, it is possible to formulate baseline values for the water now being lost, some of which could be conserved if the right measures are found and executed. The estimate of current losses is shown in Table 7-15. This estimate considers all of the District's ongoing water conservation work and does not include the water already being conserved in those programs (see Table 4-12). The values in Table 7-15 will serve as the basis for estimating benefits to be allocated to the various water conservation measures discussed in Chapters 9, 10, and 11.

Table 7-12 - Other Beneficial Water Use

Facility	AF/year
Cemeteries, Golf Courses, and Schools	
Barbara Worth Country Club	695
Central Valley Cemetery (El Centro)	27
Central Valley Cemetery (Holtsville)	16
Del Rio Country Club	994
Imperial Valley College	400
International Country Club	382
Magnolia School	110
McCabe School	120
Meadows Union School	120
Memorial Park Cemetery	39
Mountain View Cemetery	40
Pine Union School	60
Riverview Cemetery	269
Westside School	84
Subtotal	3,356
Lakes and Parks	
Finney Lake	1,614
Ramer Lake	1,696
Sunbeam Lake and Park	1,034
Wiest Lake and Park	726
Subtotal	5,070
Service Pipes	2,000
Total	10,426
Total (rounded)	10,400

Source: IID Water Conservation Plan, 1985.

Table 7-13 - Industrial, Municipal, and Other Beneficial Water Uses

Component	Water Use (AF/year) Baseline	Maximum	Minimum
Municipal	36,600	44,400	33,100
Industrial	16,800	22,200	15,600
Other beneficial uses	10,400	10,400	10,400
Total	63,800	77,000	59,100

Source: Parsons, 1985.

Table 7-14 - Total Current Water Requirements

Component	Water Requirement (AF/year) Baseline	Maximum	Minimum
Transmission losses	458,600	497,300	435,300
Agriculture	2,245,000	2,449,000	2,041,000
Industrial, municipal and other beneficial uses	63,800	77,000	59,100
Total	2,767,400	3,023,300	2,535,400
Total (rounded)	2,770,000	3,020,000	2,540,000

Source: Parsons, 1985.

Table 7-15 - Baseline Water Conservation Potential[a]

Category	AF/Year
Canal seepage	
Imperial Dam (Station 60) to Pilot Knob	80,000[b]
Pilot Knob to Drop No. 1	57,000
Drop No. 1 to Drop No. 4	18,000
Drop No. 4 to end of All-American Canal	18,000[c]
Main IID canals (150.53 total miles; 9.8 miles lined)	90,000[c]
Laterals not lined	35,000
Operational discharge	88,000
Canal evaporation	18,000
Leach water	280,000
Tailwater	270,000

[a]The component categories listed were considered potential sources of conserved water in the analysis of conservation measures presented in this report. The categories include both losses to the system (e.g., evaporation) and water now being beneficially used but potentially reclaimable (e.g., leach water).
[b]Not adjusted for underflow back to the Colorado River expected to be credited by the USBR in this reach.
[c]Adjusted to consider water recovered in seepage drains.
Source: Parsons, 1985.

Table 7-15 - Baseline Water Conservation Potential

Loss Category	AF/Year
Canal seepage	
Imperial Dam (Station 60) to Pilot Knob	80,000[a]
Pilot Knob to Drop No. 1	57,000
Drop No. 1 to Drop No. 4	18,000
Drop No. 4 to end of All-American Canal	18,000[b]
Main IID canals (150.53 total miles; 9.8 miles lined)	90,000[b]
Laterals not lined	35,000
Subtotal	298,000
Operational discharge	88,000
Canal evaporation	18,000
Leach water	280,000
Tailwater	270,000
Total	954,000 (781,000)[c]

[a]Not adjusted for underflow back to the Colorado River expected to be credited by the USBR in this reach.
[b]Adjusted to consider water recovered in seepage drains.
[c]Total, without considering All-American Canal losses.
Source: Parsons, 1985.

CHAPTER 8

FUTURE WATER REQUIREMENTS

The determination of the current water requirements of the IID in Chapter 7 established the foundation for projections of future water requirements for the year 2010. In Chapter 7, the criterion was established for determining critical values affecting water use, and a sound base was developed from which values were extrapolated to establish future water demands. The future water requirements within the IID, as discussed in this chapter, have been divided into three categories (referenced in Chapter 7):

(1) Losses within the transmission system.
(2) Agricultural requirements and accounting of all on-farm water uses.
(3) Municipal, industrial, and other nonfarm beneficial uses.

8.1 DEMAND MODELING METHODOLOGY

Estimates of future baseline water requirements (except agricultural) are based on historical data from 1975 to 1985, presented and discussed previously in Chapter 7, as well as projections made by local planning agencies. Baseline agricultural water requirements for the future are developed based on a probable future cropping pattern, increases in agricultural acreage, and the projected future salinity of supply water. These three factors directly influence the quantity of water required for agricultural purposes. Records of the historical variations of these factors formed the basis for determining future values of these parameters.

The distribution of total gross acreage within the IID for the year 2010 was based on projections of the total area devoted to agriculture, the allocation of acreage to reclaimed and fallow land uses, and the percentage of field, garden, and permanent crops to the total acres of crops. Table 8-1 summarizes the breakdown of the projected area for the year 2010 baseline scenario.

8.1.1 BASELINE WATER DEMAND SCENARIO

The most probable demand scenario for the year 2010 is based on an increase in the total area farmable in the IID to a maximum of 520,000 acres (compared to 500,000 acres used to estimate current demand). Table 8-2 presents the distribution of projected acreage per crop category and groups the crops into three major categories: garden crops, field crops, and permanent crops. Projections of the acres in each crop category for the baseline scenario in the year 2010 were derived based on the historical cropping pattern presented in Table 7-3 and the soil and crop limitations in the Imperial Valley. The marketability of selected crops grown in the Imperial Valley was also considered. The baseline demand scenario is based on the cropping pattern presented in Table 8-2.

Table 8-1 - Summary of Projected Area Served (year 2010)

Land Use	Baseline Area (acres)
Field crops	410,000
Garden crops	97,000
Permanent crops	18,000
Total acres of crops	525,000
Total duplicate crops	90,000
Total net acres in crops	435,000
Area being reclaimed (leached)	5,000
Net area irrigated	440,000
Area farmable but not farmed during year (fallow land)	80,000
Total area farmable	520,000
Area of farms in homes, feedlots, corrals, cotton gins, experimental farms, and industrial areas	15,000
Areas in cities, towns, airports, cemeteries, fairgrounds, golf courses, recreational parks and lakes, and rural schools, less area being farmed	23,000
Total area receiving water	558,000
Area in drains, canals, rivers, railroads, and roads	75,000
Area below -230-ft Salton Sea reserve boundary and area covered by Salton Sea, less area receiving water	39,000
Area in Imperial Unit not entitled to water	64,000
Undeveloped area of Imperial, West Mesa, and Pilot Knob units	239,290
Total acreage included (all units)	975,290
Acreage not included (all units)	87,000
Total gross acreage within District boundaries	1,062,290

Note: Alfalfa acreage reduced by factor of 0.793 per DWR, 1981.
Source: IID Water Reports, 1975-1984.

Table 8-2 - Summary of Projected Acreage per Crop Category (year 2010)

Crop	Baseline Area (acres)
Garden Crops	
Broccoli	7,000
Carrots	12,000
Lettuce	35,000
Cantaloupes	15,000
Watermelons	5,000
Other melons	4,000
Onions	10,000
Squash	1,000
Tomatoes	3,000
Vegetables (misc)	5,000
Total	97,000
Field Crops	
Alfalfa	185,000
Barley	1,000
Bermuda grass	15,000
Cotton	40,000
Rye grass	4,000
Sorghum	3,000
Sudan grass	20,000
Sugar beets	35,000
Wheat	105,000
Cereals (misc)	2,000
Total	410,000
Permanent Crops	
Asparagus	3,000
Citrus fruits	2,000
Duck ponds (feed)	8,000
Jojoba	3,000
Trees and vines	1,000
Miscellaneous	1,000
Total	18,000
Total acres of crops	525,000

Note: Alfalfa acreage reduced by factor of 0.793 per DWR, 1981.
Source: IID Water Reports, 1975-1984.

8.1.2 DEMAND VARIATIONS

The planning maximum and planning minimum demands are formulated for the year 2010 using exactly the same methodology as applied to the current water requirements in Chapter 7. The year 2010 baseline is used as the center of a range within which 90% of the agricultural demands are expected to fall. The other demand components, e.g., industrial requirements, are estimated using the latest planning data available.

8.2 TRANSMISSION AND DISTRIBUTION SYSTEM LOSSES

Transmission and distribution system losses are the result of seepage, evaporation, operational discharge, and other minor water losses. Although most water lost is not measured, estimates can be made to develop future scenarios. The installation of more recording gauges would aid in refining these estimates. A summary of the estimated transmission and distribution system losses is presented in Table 8-3. Seepage is projected to remain the major source of water loss. The projected quantities for all losses were based on the assumption that no water conservation measures above current levels are undertaken, including canal lining and automated water distribution system controls.

Table 8-3 - Transmission and Distribution System Losses (year 2010)

Component	Water Loss (AF/year)		
	Baseline	Maximum	Minimum
Main Canals and Laterals (below Drop No. 4)			
Seepage	175,000	175,000	175,000
Evaporation[a]	19,000	21,000	18,000
Operational discharges	88,000	96,000	80,000
Subtotal	282,000	292,000	273,000
Imperial Dam to Drop No. 4			
All-American Canal seepage	155,000	155,000	155,000
Evaporation	7,600	8,300	7,100
Ordered but delivered to Mexico in excess of treaty	14,000	50,000	0
Subtotal	176,600	213,300	162,100
Total	458,600	505,300	435,100

[a]Includes evaporation from four existing reservoirs of 1,000 AF/year.
Source: Parsons, 1985.

Baseline transmission and distribution system losses for the year 2010 are identical to the figures estimated for the current water requirements. The estimate for the maximum water demand scenario for the year 2010 was increased by 8,000 AF/year from the 1985 estimate on the basis of an increase in the quantity of water delivered and the fact that no additional conservation measures are undertaken. Operational discharges are often a function of the volume of water delivered to users; therefore, estimates of maximum and minimum discharge losses were determined by adjusting the baseline estimate in relation to variations in the applied water for maximum and minimum water demands.

The projected baseline total for transmission and distribution system losses in the future scenario is approximately 459,000 AF/year. The projected maximum and minimum totals are 505,300 and 435,100 AF/year, respectively.

8.3 AGRICULTURAL WATER REQUIREMENTS

Agricultural water use in the year 2010 is projected to remain the greatest water use within the IID, and it is subdivided for this study into three categories:

(1) Crop consumptive use
(2) Leaching
(3) Tailwater

Water required for crop consumptive use is calculated on the basis of the projected cropping pattern in the year 2010 and on the crop evapotranspiration unit values presented in subsection 7.3.1. Miscellaneous on-farm water uses account for less than 1% of the total agricultural requirement and are assumed to be included within the crop consumptive use category. Tailwater and water required for leaching are projected from current water requirements estimated in Chapter 7.

Detailed procedures and discussions of each agricultural component have been presented in section 7.3. In the following subsections, the rationale for estimating future water use projections is discussed in brief.

8.3.1 CROP CONSUMPTIVE USE

In this subsection, consumptive use of applied water is projected to the year 2010 for each crop category developed in Table 7-3. The crop consumptive use was calculated using the crop evapotranspiration unit values and the effective precipitation values presented in Table 7-6 for the current agricultural water requirements. This selection of unit values was discussed in subsection 7.3.1, along with the rationale for determining effective precipitation.

Evapotranspiration unit values adjusted for effective precipitation are multiplied by projected crop acreages listed in Table 8-2 to yield the consumptive use of applied water for baseline conditions. Table 8-4 presents the consumptive use requirement, which is estimated at 1,771,000 AF/year for the year 2010. Compared to the current baseline water demand scenario, there would be an increase of about 76,000 AF/year.

Table 8-4 - Crop Consumptive Use

Crops	Area[a] (acres)	ET[b] (ft)	EP[c] (ft)	CU of AW[d] (AF)
Garden Crops				
Broccoli	7,000	1.7	0.06	11,480
Carrots	12,000	1.3	0.09	14,540
Lettuce	35,000	1.4	0.06	47,017
Cantaloupes	15,000	2.3	0.09	33,213
Watermelons	5,000	2.3	0.11	10,929
Other melons	4,000	2.3	0.07	8,903
Onions	10,000	1.9	0.13	17,725
Squash	1,000	1.7	0.12	1,578
Tomatoes	3,000	2.3	0.07	6,695
Vegetables (misc)	5,000	1.7	0.08	8,083
Subtotal	97,000			160,163
Field Crops				
Alfalfa	185,000	5.4	0.22	961,692
Barley	1,000	1.8	0.15	1,650
Bermuda grass	15,000	3.6	0.13	52,125
Cotton	40,000	3.6	0.15	137,900
Rye gras	4,000	2.5	0.13	9,500
Sorghum	3,000	2.5	0.06	7,330
Sudan grass	20,000	2.5	0.13	47,500
Sugar beets	35,000	3.7	0.21	122,208
Wheat	105,000	2.1	0.15	204,488
Miscellaneous	2,000	2.5	0.15	4,695
Subtotal	410,000			1,549,088
Permanent Crops				
Asparagus	3,000	4.2	0.08	12,355
Citrus fruits	2,000	3.8	0.22	7,163
Duck ponds (feed)	8,000	3.0	0.00	24,000
Jojoba	3,000	3.8	0.22	10,745
Trees and vines	1,000	3.8	0.22	3,582
Miscellaneous	1,000	4.2	0.22	3,982
Subtotal	18,000			61,827
Total acres of crops	525,000			1,771,077
Total, rounded	525,000			1,771,000

[a]Based on historical cropping pattern presented in Table 7-3, soil and crop limitations, and the marketability of selected crops in the Imperial Valley.
[b]Evapotranspiration unit values.
[c]Effective precipitation, based on 90% of 71-year average monthly rainfall conditions (Appendix Table E-3) and determined for each crop using the crop calendar published by IID and monthly EP values.
[d]Consumptive use of applied water: area x (ET-EP).
Source: Blaney and Criddle, 1962; UA, 1968; Kaddah and Rhodes, 1976; Donovan and Meek, 1983; DWR, 1983c; Parsons, 1985.

8.3.2 LEACHING

Water required for leaching in the year 2010 is dependent on the future water quality of the Colorado River. In Chapter 3 (subsection 3.1.4), the estimates of the salinity of irrigation water were presented. The USBR has estimated the salinity at Imperial Dam to be approximately 900 mg/L for the year 2010, assuming a continuation of planned salinity control projects (USBR, 1985). The salinity levels used for the current water requirement in Chapter 7 were estimated at approximately 795 mg/L, measured as TDSs. The water required for leaching is estimated from the leaching quantity determined in subsection 7.3.2 for current water requirements based on the projected salinity in the year 2010. The ratio of projected salinity in the year 2010 to that of the current salinity is multiplied by the water required for leaching in 1985 to estimate a future leaching requirement of 320,000 AF/year.

8.3.3 TAILWATER

The determination of tailwater for the year 2010 is based on the tailwater quantity estimated for the current water requirements in subsection 7.3.3. Assuming that no additional water conservation actions aside from existing programs are taken, tailwater will remain approximately 12% of the total agricultural water requirement. Based on this percentage, tailwater is estimated to increase 20,000 AF by the year 2010 to a total of 290,000 AF/year.

8.3.4 TOTAL AGRICULTURAL WATER REQUIREMENT

Projections of year 2010 total agricultural water requirements are presented in Table 8-5. The projected baseline total for the future agricultural water requirement is estimated at 2,381,000 AF.

Table 8-5 - Total Agricultural Water Requirement

Component	Water Use (AF/year)[a]		
	Baseline	Maximum	Minimum
Consumptive use	1,771,000	1,932,000	1,610,000
Leaching	320,000	349,000	291,000
Tailwater	290,000	316,000	264,000
Total	2,381,000	2,597,000	2,165,000

[a]Maximum and minimum values determined by statistical analysis.
Source: Parsons, 1985.

8.4 OTHER REQUIREMENTS

Other water requirements include municipal, industrial, and miscellaneous beneficial water uses. Although industrial water use represents the greatest quantity of water projected for these three categories, it is not highly significant when compared to the agricultural water use, accounting for less than 10% of the total future water requirements.

8.4.1 MUNICIPAL WATER USE

Projections have been made of municipal water use in the year 2010 and are presented in Table 8-6. The determination of the municipal water uses for baseline, minimum, and maximum future water demand scenarios was based on projected population estimates for the year 2010 shown in Tables 2-12, 2-13, and 2-14, respectively, and conventional gallons per capita per day (gpcd) values from Chapter 7. Municipal water demands for the year 2010 baseline conditions were based on 1.75% population growth rate and the 5-year weighted average gpcd values from Table 7-9. The maximum demand projection for the municipal water requirements in the year 2010 was estimated by using the historical maximum gpcd values from Table 7-8 and the extrapolated population totals from Table 2-14. The maximum population totals were based on a growth rate of 2.45%. The minimum demand projection was obtained by the substitution of the historical minimum gpcd values from Table 7-8 and the minimum predicted population totals of Table 2-13, assuming a 1.56% population growth rate.

The year 2010 municipal water demands shown in Table 8-6 include water that is received directly from the canal system and individually treated by farmers in rural areas and communities. The predicted baseline total for municipal water use is 56,500 AF. The estimated maximum municipal water use is 81,300 AF and the minimum is 48,800 AF.

8.4.2 INDUSTRIAL WATER USE

Projections of total water requirements in the year 2010 include estimates of industrial water uses, which are subdivided into the following categories: industrial, geothermal, feedlots, and the U.S. Naval Air Station. Future water use for geothermal industries is projected to greatly increase from present levels of 1,000 AF/year to approximately 72,500 AF. The industrial subcategory is projected to increase in proportion to the projected population increase for each of the demand scenarios shown in Table 8-7.

Industrial water uses in Table 7-11 were extrapolated to reflect population increases in the year 2010. Future projections for the U.S. Naval Air Station and feedlots are assumed to be independent of projected population increases and to remain the same as the baseline, maximum, and minimum estimates for the current industrial water use requirements as presented in Table 7-11. The year 2010 projected industrial water use total for baseline conditions is 90,000 AF and could range from 13,000 AF to 266,000 AF as shown in Table 8-7.

Table 8-6 - Municipal Water Use

Town/Area	Baseline			Minimum			Maximum		
	Population	gpcd	AF/yr	Population	gpcd	AF/yr	Population	gpcd	AF/yr
Brawley	27,212	451	13,736	26,000	414	12,061	32,300	548	19,817
Calexico	26,120	290	8,483	24,956	258	7,210	31,003	314	10,905
Calipatria	4,140	417	1,932	3,955	387	1,712	4,914	526	2,893
El Centro	42,123	231	10,886	40,248	211	9,513	49,999	285	15,968
Heber	3,691	141	584	3,526	104	411	4,381	162	793
Holtville	7,218	320	2,584	6,897	274	2,119	8,568	363	3,488
Imperial	5,970	473	3,165	5,704	433	2,765	7,086	809	6,419
Niland	1,731	625	1,213	1,654	296	548	2,055	876	2,015
Seeley	1,757	293	577	1,679	286	537	2,086	313	730
Westmorland	2,856	499	1,596	2,729	365	1,116	3,390	764	2,902
Nonurban	32,369	325	11,788	30,927	313	10,844	38,421	356	15,322
Total	155,187	325	56,543	148,275	281	48,836	184,203	467	81,254
Total (rounded)	155,200		56,500	148,300		48,800	184,200		81,300

Note: The above populations were calculated using different percentage growth rates. For the baseline, minimum, and maximum populations, growth rates of 1.75%, 1.56%, and 2.45%, respectively, were used (see subsection 2.3.2 for development of growth rates).

Source: Parsons, 1985.

Table 8-7 - Industrial Water Use

Delivered Water	Water Use (AF/year) Baseline	Maximum	Minimum
Industrial	5,800	12,000	3,700
Geothermal	72,500	240,000	0
Feedlots	11,100	13,400	8,900
U.S. Naval Air Station	600	700	500
Total	90,000	266,100	13,100

Source: Parsons, 1985; IID Water Conservation Plan, 1985.

8.4.3 OTHER BENEFICIAL USES

The projection of future total water requirement in the year 2010 includes estimates of other beneficial water uses. The major categories of beneficial water use within IID include irrigation of cemeteries, schools, and golf courses as well as recreational uses such as lakes and parks. Future baseline water demand for irrigation and recreational uses is projected to increase in proportion to population estimates for the year 2010 (presented in Table 2-12). The remaining components are expected to remain roughly at current (1985) levels. Beneficial water use projections for maximum and minimum water demand scenarios are based on minimum and maximum population projections for the year 2010 shown in Tables 2-13 and 2-14, respectively. A summary of the projected beneficial water uses for the future water demand scenario is shown in Table 8-8.

Table 8-8 - Other Beneficial Water Use

Facility	Water Use (AF/year) Baseline	Maximum	Minimum
Cemeteries, golf courses, and schools	5,200	6,100	4,900
Lakes and parks	7,800	9,300	7,500
Service pipes	2,000	2,000	2,000
Total	15,000	17,400	14,400

Source: Parsons, 1985.

8.5 TOTAL FUTURE WATER REQUIREMENTS

The projection of total water requirements in the year 2010 is determined by summation of the various items discussed previously. Table 8-9 summarizes the projected future water demands for the different scenarios by catgegory. The total future water requirement for baseline conditions is projected to be 3,000,000 AF. The projected maximum and minimum totals are 3,500,000 AF and 2,700,000 AF, respectively.

Table 8-9 - Total Future Water Requirement

Component	Water Requirement (AF/year)		
	Baseline	Maximum	Minimum
Transmission losses	458,600	505,300	435,100
Agriculture	2,381,000	2,597,000	2,165,000
Municipal	56,500	81,300	48,800
Industrial	90,000	266,100	13,100
Other beneficial uses	15,000	17,500	14,500
Total	3,001,100	3,467,200	2,676,500
Total (rounded)	3,000,000	3,500,000	2,700,000

Source: Parsons, 1985.

CHAPTER 9

STRUCTURAL WATER CONSERVATION METHODS: DISTRICT CONTROLLED

This chapter analyzes the structural measures considered worthy of evaluation for implementation by the IID in its further efforts to conserve water. Each conservation alternative is described in detail, analyzed to determine technical and economic feasibility [using benefit/cost (B/C) ratio methodology], and then considered from the standpoint of environmental impact. In the process of determining the benefits resulting from specific conservation measures, it was necessary to estimate the amount of water conserved when a particular project would be implemented. These estimates were based largely on engineering judgment, coupled with the use of the data available. An effort has been made to be conservative; for example, only 90% of the assumed seepage was used as a benefit when a canal is lined, while a value greater than 95% could have been supported. Nevertheless, the benefit/cost ratios calculated in this report are approximate and must be refined iteratively as the conservation program progresses and results become better defined. The same position holds for analyses done in Chapters 10 and 11.

The analysis of economic feasibility also required several critical assumptions listed as follows:

(1) Water conserved has a hypothetical (conservative) value of \$100/AF/year in 1985 dollars. The potential amounts allocated to various categories are as shown at the end of Chapter 7.

(2) The interest rate for present worth calculations is 8.125%.

(3) The baseline life of capital projects is 40 years (in specific cases shorter lifetimes are used).

(4) Costs incurred for engineering and construction are all incurred in the first year. Annual costs are included for 40 years.

(5) Benefits begin to accrue in the fourth year and continue for 37 years (40 - 3 = 37).

Assumption 1 is the most critical in determining the actual numerical value of the final benefit/cost. The value of \$100/AF conserved was selected because:

(1) It represents very close to the minimum value that could reasonably be used.

(2) It facilitates rapid adjustment of results in sensitivity analyses.

(3) It is completely adequate for the purpose of comparing alternatives.

Other studies such as the USBR Special Report on conservation opportunities in the IID have used much higher numbers, and a case could be made for values of over $1,000/AF, depending on the options available to a potential user of transferred water. Therefore, the benefit/cost ratios for various alternatives considered in this study can be considered very conservative.

Assumption 2 is representative of current economic conditions, and assumption 3 is consistent with standard practice in the economic analyses of facilities such as canals and related physical works.

Assumption 4 is possible because, as much as is feasible, the projects discussed in this report can and are expected to be divided into small discrete elements that can be completed in less than 1 year and immediately placed in service. For example, a regulating reservoir could be constructed in a relatively short time and put on-line immediately. Major canal lining projects will be compartmentalized so that results can be realized within months after construction begins, utilizing appropriate transition structures to ensure that service is not interrupted. Using small construction projects appropriately spaced ensures less environmental impact, better cash flow, greater opportunity for local contractors, and an ease of assimilation by the District's staff. Assumption 5 assumes the project will operate for 3 years before any agreement is reached that allows monetary benefit to be realized on the water conserved by a specific project.

9.1 SALINITY CONTROL

Perhaps the most pervasive problem that the IID and Imperial Valley farmers face is salt buildup in the soil. The negative effect of high salt levels is well documentated, and the corresponding need for leach water is one of the largest single demands that the IID must meet. This section addresses that vital issue. It is dealt with as the first section of this chapter because any program to conserve water must have as a fundamental element a measure to provide some security against the uncertainties of potential salinity increases in Colorado River water. With the expected salinity control measures mandated by the federal government, a salinity increase of 80 ppm is still forecast. This potential variation was introduced in Chapter 3, and a solution is presented in this section.

9.1.1 DESCRIPTION

The most direct solution for this problem is desalination of incoming Colorado River water. Desalination could take place at numerous points upstream of the District (e.g., treatment of Palo Verde return flows). However, the IID's control over operations far afield from the Imperial Valley would be reduced, and disposal of brine might be more difficult. Therefore, distant sites are not considered in this report. A second concept would be to provide desalination of IID drain water and then reuse it. However, because the other programs discussed in this report are expected to dramatically reduce tailwater, seepage, and operational discharge, desalination will be aimed at the most efficient method of holding leach water at present levels or even reducing it by eliminating salt before it enters the system. Therefore, the salinity control measure considered in this study will consist of a desalination plant located near Drop No. 1 or No. 4. The exact location will depend on whether Coachella is interested in the joint development of such a plant. If so, the plant will be located upstream of the Coachella Canal diversion; if not, the IID will select an appropriate site near Drop No. 4. For this report, it is assumed that the IID must develop the project alone, and the site proposed would be near the East Highline diversion.

The plant proposed would have the capacity to treat 300,000 AF/year (approximately 270 MGD), which would reduce the average inflow TDS concentration by approximately 100 ppm. This should provide adequate protection to keep IID's salinity at approximately the present level even if there is an increase in salinity at Imperial Dam. The brine flow from the plant would be on the order of 30,000 AF/year and would be disposed of in the most environmentally acceptable manner.

9.1.2 BENEFITS AND COSTS

The benefits expected from a desalination plant are twofold:

(1) Reduced leach water
(2) Better farm output

The first of these benefits can be estimated with reasonable accuracy. The second cannot be defined well enough at this time for use in the economic analysis; however, it can at least be noted as an amenity.

Based on the current leaching requirement of 280,000 AF/year, it is estimated that the salinity reduction of 100 ppm envisioned for this plant will save about 60,000 AF/year; however, the 30,000 AF/year of brine produced makes the net gain only 30,000 AF/year. This will not offset the costs of building and operating the plant. Nevertheless, the plant is considered important for control of salinity in the District and will therefore not be considered from the standpoint of a classical benefit/cost analysis. Instead, the facility cost will be defined and, later in the report, those costs will be prorated to the other components of the recommended conservation system. At that time, a "system benefit/cost function" will be derived.

The estimated system costs are:

$$\text{Capital cost} = \$335{,}000{,}000$$

This cost is based on the cost of similar facilities near Yuma, Arizona. The annual cost associated with this capital investment is:

$$\text{Capitalized annual cost} = \frac{0.08125(1.08125)^{40}}{(1.08125)^{40} - 1} \$335 \times 10^{6}$$
$$= \$28{,}470{,}000$$

The annual O&M cost for the plant is about $0.55/1,000 gallons, which means:

$$\text{Annual O\&M cost} = \$53{,}800{,}000$$

The total annual cost is thus:

Capital cost = \$28,470,000
O&M cost = 53,800,000

Total \$82,270,000

The unit cost per acre-foot treated is:

$$\text{Cost/AF} = \frac{\$82,270,000}{300,000}$$

$$= \$274/\text{AF treated}$$

The remaining economic analyses in this chapter will be conducted by defining a benefit/cost ratio to justify further consideration of each alternative for conserving water.

9.1.3 ENVIRONMENTAL CONSIDERATIONS

A. Terrestrial Biology

Salt builds up in the soil in wetlands and other seepage areas near canals and drains. If salinity was decreased, salt in the soil would be decreased through leaching. As a result of lower soil and water salinities, plant species should become more diverse and species composition would change, selecting more plants adapted to the lower salinity.

B. Aquatic Biology

Lower salinity in canals and drains would have similar effects on aquatic biology as described above for terrestrial biology. Species more adapted to lower salinity would probably increase in number, and new species might appear if they have an upstream source. These changes would be expected among plankton, benthic macroinvertebrates, and possibly macrophytes.

C. Water Quality of the Salton Sea

As a result of a decrease in salinity, less water would be required for soil leaching. Consequently, flow into the Salton Sea would be reduced, thus reducing dilution and increasing salinity in the sea.

D. Other Considerations

Impacts could occur from construction of desalination plants. Noise, fugitive dust and particulate emissions, and transportation impacts would occur but would be short term and of small magnitude; therefore, they should be of little significance. Desalination plant operation would create air pollutants, but proper air emission controls would mitigate adverse impacts to ambient air quality. Waste brine from desalination plant operation would have to be disposed of properly to avoid environmental impacts. Properly certified disposal sites that are available in Imperial County may be used, or an environmentally sound alternative should be sought that would not damage terrestrial or aquatic ecosystems.

9.2 CANAL LINING

It has been well documented in various District and USBR reports that canal lining is of benefit in water conservation. It is estimated that canal seepage accounts for approximately 35% of the total system losses previously shown in Chapter 7. It is certain that seepage does represent the major portion of all canal system losses. Both the District and the USBR are in agreement that benefits of canal lining are:

(1) Infiltration losses reduced to a minimum.
(2) Maintenance costs reduced, including removal of aquatic weeds.
(3) Conveyance efficiency increased.
(4) ROW requirement decreased, thereby returning land to agriculture.
(5) Evaporation reduced from the reduced water surface.
(6) Seepage-recovery pumping systems and associated costs eliminated.
(7) Accuracy of flow measurement increased.

9.2.1 DESCRIPTION

To date, only sections of laterals and minor canals have been lined in the District. These laterals and minor canals are periodically taken out of service, for a few days at a time, for routine maintenance. During these service shutdowns, canals and/or laterals can be lined. Of the main canals, only the small (320 ft^3/sec) New Briar Canal is lined. This canal was lined at the time of construction.

The All-American Canal, East Highline Canal, Central Main Canal, and Westside Main Canal are completely unlined, except in the immediate vicinities of drop structures. These major canals cannot be taken out of service at any time without imposing unacceptable economic loss on the District. Therefore, in any acceptable lining program for these canals, bypass channels must be excavated and placed in service. When the Coachella Canal of the Coachella Water District was lined, a new channel was excavated parallel to the Coachella Canal for its entire length. The new channel was lined while all flows were maintained through the existing channel.

A similar procedure for lining of the District's major canals is indicated. For the East Highline Canal, the bypass channel would probably lie entirely, or almost entirely, east of the existing canal to prevent damage to existing farmlands at any time. The choice of which channel to line, and the ultimate disposal of the temporary bypass channel, will require study. Similarly, for the Westside Main Canal, the bypass channel would probably lie west of the main channel as far as the beginning of the Thistle Canal. The remainder of the Westside Main Canal and the entire length of the Central Main Canal will require careful study to determine where the temporary bypass channel should be located in order to minimize damage to farming operations. Similarly, the All-American Canal presents major problems in bypassing flows during lining. Parts of the All-American Canal (particularly west of Calexico) run in a narrow ROW between irrigated farmlands and the Mexican border. Other parts of the All-American Canal were excavated through high sandhills. In all of these cases, the lining program would be conducted in discrete reaches, as mentioned in the introduction to this chapter.

The District's present practice is to use concrete for all canal linings. It is possible that other materials might be indicated in some instances. These other materials will be evaluated later; some offer interesting possibilities, while others seem unlikely to prove cost-effective. However, to evaluate the proposed canal-lining materials with a high degree of confidence, all materials currently available will need to be considered. Such materials include, but are not limited to, the following:

(1) Mixed-in-place soil cement.
(2) Asphaltic liner (preformed or formed-in-place).
(3) Bentonite liner (mixed with natural soil or spread on top of same).
(4) Compacted earth linings with waterproofing chemical admixtures.
(5) Cement/asphalt mixtures with various aggregates.

A further consideration in canal lining is that lining changes the hydraulic properties. Under open-channel conditions, flow velocity is higher (for a given discharge) in a lined canal than in an unlined canal. Correspondingly, an equal discharge has less water depth in a lined canal of a similar section. Canal hydraulics must be compared between lined and unlined sections under two different flow conditions: unimpeded open-channel flow and open-channel flow with canal checks lowered to raise the water surface elevation. In some instances, a smaller canal cross section will be required after lining.

The specific system used for this analysis will consist of a concrete lined, trapezoidal, open-channel section, with 1.5:1 side slopes and with appropriate capacities.

9.2.2 BENEFITS AND COSTS

The benefit of canal lining is in the conservation of an estimated 90% (value assumed for this report - actual value probably higher) of the seepage that occurs in an unlined canal. In calculating seepage benefits, it is assumed that all main canals, as well as the All-American Canal, are water-filled at all times, whereas the average lateral canal is water-filled 90% of the time. The benefits and costs vary considerably among the various canals. Benefits vary because the permeability of soil varies considerably from place to place. As a consequence, seepage rates also vary.

Costs vary considerably. Lateral canals are periodically taken out of service for maintenance. At such times, lining can be placed without disruption of farm operations and without any additional temporary ROWs. The main canals and the All-American Canal must remain in service at all times; consequently, parallel channels must be provided for water delivery during lining. This is true whether the existing channel is to be lined as proposed (as for the East Highline Canal) or whether a totally new channel is lined (e.g., the existing Coachella Canal). Parallel channels can be excavated in unused public land at the East Highline Canal, over one-half the length of the Westside Main Canal, and along the All-American Canal east of the East Highline Canal turnout. Parallel channels for the remainder of the All-American Canal, the Westside

Main Canal, and the whole of the Central Main Canal must be excavated across developed agricultural land, and the landowners must be compensated appropriately.

A. The All-American Canal

For the purpose of this study, the lining of the All-American Canal was calculated based on the design flows and analysis of the design canal sections and on the gradients originally constructed. For the benefit/cost calculations, the All-American Canal was divided in four major reaches:

(1) Imperial Dam headworks to Pilot Knob
(2) Pilot Knob to Drop No. 1
(3) Drop No. 1 to Drop No. 4
(4) Drop No. 4 to Westside Main

The following data was used for the benefit/cost calculations:

(1) Seepage losses shown on Table 7-20.

(2) Decrease in maintenance was calculated based on the District's O&M expenditures (IID Water Report, 1984). This expenditure was assumed to be 70% for operations and 30% for maintenance. It was further assumed that maintenance would be reduced by two-thirds when the canal was lined.

1. Imperial Dam Headworks to Pilot Knob Check. For this reach, it was assumed, for the most part, that a bypass canal would be constructed to carry the flows while the existing canal was dewatered, reshaped and lined. Material obtained from the canal in cut areas would be used to construct canals in fill areas. All of the existing structures such as siphons, wash overchutes, railroad, and highway bridges would be retained. Major expenditures would be incurred in providing temporary bypass structures under railroads and interstate highways. It was assumed that construction at wash/overchutes and siphons would be scheduled for the dry season, thus eliminating the cost of providing temporary structures. Land required for bypass canals was assumed to be obtained at no cost. The benefit cost calculations are summarized in Table 9-1.

2. Pilot Knob Check to Drop No. 1. For estimating purposes, this reach was divided into three subreaches. From Pilot Knob Creek to the start of the Pilot Knob hills, a bypass canal was assumed similar to the one used in the upstream reach. Through the Pilot Knob hill, the existing section in rock cut was assumed to be left undisturbed (no lining). From the rock section to Drop No. 1 (and Coachella Turnout), a new canal was excavated and lined and the old canal was abandoned or used for excavation disposal. This new canal would be constructed on the north side of the old one to avoid ROW interference with the interstate highway and International Border. The land requirements for the bypass and new canal were assumed obtained at no cost. The benefit/cost calculations are summarized in Table 9-1.

Table 9-1 - Canal Lining Summary of Benefit/Cost Estimates (1985 dollars)

Canal Reach	1,000 AF/year		$1,000							
	Seepage Losses	Water Conserved	Water Benefit (per year)	Decreased Maintenance (per year)	Total Benefit Present Worth	Construction Cost	Land Cost Present Worth	Total Cost	Benefit/Cost Ratio	Cost/AF Required for Benefit/Cost of 1.00 ($)
All-American Canal Imperial Dam to Pilot Knob Check	50[a]	45	4,500	71	42,000	54,000	0	54,000	0.78	129
Pilot Knob Check to Drop No. 1	57	51	5,100	55	47,400	32,000	0	32,000	1.48	68
Drop No. 1 to Drop No. 4	18	16	1,600	58	15,200	21,200	0	21,200	0.72	139
Drop No. 4 to Westside Main	18	16	1,600	100	15,600	25,200	406	25,606	0.61	164
East Highline Canal	51	46	4,600	156	43,700	39,500	0	39,500	1.11	90
Central Main Canal	10	9	900	74	8,960	18,600	321	18,921	0.47	211
Westside Main Canal	25	22	2,200	127	21,400	31,000	257	31,357	0.68	147
Vail Canal	2	2	200	2	1,860	1,000	0	1,000	1.86	54
Rositas Canal	2	2	200	2	1,860	940	0	940	1.98	51
Lateral Canals	39	35	3,500	2,000	53,391	47,400	0	47,400	1.13	89

[a]Reduced by 30,000 AF/year to account for probable credit to be granted to the IID for underflow that returns to the Colorado River.
Source: Parsons, 1985.

3. Drop No. 1 to Drop No. 4. To avoid interference with the interstate highway, it was assumed that from Drop No. 1 a new canal would be constructed on the south side of the existing canal using the constructed south berm of the existing canal as much as possible. The old canal would be abandoned as the new canal is placed into service. It was assumed that the new canal would be joined to the existing drop structures, thus avoiding construction of new structures. The land required for the construction of the new canal was assumed to be obtained at no cost. The benefit/cost calculations are summarized in Table 9-1.

4. Drop No. 4 to Westside Main Headworks. The lining of this reach presents the most complicated problems when it enters the agricultural land of the District or in the areas along the International Border. For the purpose of this study, it was assumed that a new lined canal would be constructed from Drop No. 4 to a point just downstream from Mesa Lateral 2. The old canal would be abandoned or reverted to agricultural use. From Mesa Lateral 2 to the Westside Main headworks, a bypass canal would be constructed on the north of the existing canal to carry the flows while the old canal was dewatered, reshaped, and lined. In the areas away from the International Border, north of Calexico, the bypass canal was assumed on the north side of the existing canal for estimating purposes. Whether a southern route is most beneficial would require further detailed study. The agricultural areas used for the construction of the temporary bypass canal were assumed leased from landowners for a period of 3 years during the incremental reconstruction of the existing canal. Agricultural lands were assumed to be leased at $1,000.00/acre/year. These lands would be returned to agricultural use after completion of the lining operations. The benefit/cost calculations are summarized in Table 9-1.

B. East Highline Canal

The lining of the East Highline Canal was based on estimated flows derived from data on hand, estimated sections based on data on hand, and profiles on hand.

The East Highline Canal lies at the toe of East Mesa. Low sand dunes and gently rolling low hillocks extend easterly toward higher ground. Only slight development exists, e.g., a few gravel pits, east of the East Highline Canal. Developed agricultural land lies to the west of the canal for its entire length, at a short distance. It was assumed that a bypass channel would be constructed east of the existing canal in a small number of long reaches. Temporary piped connections would carry water supplies to existing turnouts on the existing channel. The existing channel would be dewatered, reshaped, and lined, and the existing turnouts reconnected as each long reach of canal was lined and returned to service. Existing structures (e.g., the East Highline hydroelectric power plant, weirs, checks, and bridges) would be retained. Bridges meeting applicable standards would cross the temporary bypass channel.

Upon completion of lining of the East Highline Canal, the bypass channel would be retained for flood protection of the East Highline Canal.

Benefit/cost calculations were based on a methodology similar to that used for the All-American Canal (see subsection 9.1.2.A, above). The benefit/cost calculations are summarized in Table 9-1).

C. Central Main Canal

The lining of the Central Main Canal was based on estimated flows derived from data on hand, estimated sections based on data on hand, and profiles on hand.

The Central Main Canal flows through developed agricultural land, with irrigated farms on both sides of the canal for its entire length. It was assumed that a bypass channel would be constructed to the south and west of the existing Central Main Canal, in a small number of long reaches, on leased land. Temporary pipe connections would carry water supplies to existing turnouts on the existing canal. The existing canal would be dewatered, reshaped, and lined; the existing turnouts would be reconnected as each long reach of canal was lined and returned to service. Existing structures (e.g., the double-weir hydroelectric powerplant, weirs, checks, and bridges) would be retained. Bridges meeting applicable standards would cross the temporary bypass channel.

Upon completion of lining, each long reach of canal and the temporary bypass channel would be filled in, regraded, and returned to the landowner in acceptable condition for agriculture.

Benefit/cost calculations are based on a methodology similar to that used for the All-American Canal (see subsection 9.1.2.A, above). The benefit/cost calculations are summarized in Table 9-1.

D. Westside Main Canal

The lining of the Westside Main Canal was based on estimated flows derived from data on hand, estimated sections based on data on hand, and profiles on hand.

The Westside Main Canal lies largely at or near the toe of the West Mesa; however, the reach from the Filaree Canal turnout to the Thistle Lateral 8 spill flows through developed agricultural land, with irrigated farms on both sides. It was assumed that a bypass channel would be constructed to the west of the existing Westside Main Canal in a small number of long reaches. From the All-American Canal to the Filaree Canal turnout, the bypass channel would lie on public land. From the Filaree Canal turnout to the Thistle Lateral 8 spill, the bypass channel would lie on leased land. Finally, north of the Thistle Lateral 8 spill, the bypass channel would again cross public land. Temporary pipe connections would carry water supplies to existing turnouts on the existing canal, which would be dewatered, reshaped, and lined; the existing turnout would be reconnected as each long reach of canal was lined and returned to service. Existing structures (e.g., the Turnip Drop hydroelectric powerplant, weirs, checks, and bridges) would be retained. Bridges meeting applicable standards would cross the temporary bypass channel.

Upon completion of lining, each long reach of canal and the temporary bypass channel would be retained for flood protection (if on public land) or filled in, regraded, and returned to the landowner (if leased).

Benefit/cost calculations were based on a methodology similar to that used for the All-American Canal (see subsection 9.1.2.A, above). The benefit/cost calculations are summarized in Table 9-1.

E. Vail Supply Canal and Rositas Supply Canal

The Vail Supply Canal and Rositas Supply Canal run from the East Highline Canal to service areas west of the Alamo River. Each canal crosses under the Alamo River in a siphon. The lining of the Vail Supply Canal and Rositas Supply Canal was based on known flows and known topography.

Each canal will be replaced by a concrete-lined canal immediately south of the old canal. The new lined canals will connect to existing siphons under the Alamo River. Temporary farm turnouts will cross the new canals prior to their being placed in service. After completion of the new canals, excavated material will be wasted in the abandoned former channels. The former ROW will be exchanged for the new ROW. Due to the small size of channels, very little land area will be involved.

F. Lateral Canals

The District has a program for lining lateral canals that has been in operation for several years. The methodology is well developed. In this study, it is assumed that lateral canals will be lined using existing procedures and criteria. The lining was based on known flows, know topography, and the District's design standards.

Benefit/cost calculations were based on methodology similar to that used for the All-American Canal (see subsection 9.1.2.A, above). The benefit/cost calculations are summarized in Table 9-1.

G. Canal Lining Benefit/Cost Analysis

1. All-American Canal. Based on the results shown on Table 9-1, the All-American Canal reach between Pilot Knob Check and Drop No. 1 appears to be the most viable option for lining and presents an excellent opportunity for immediate consideration for implementation. The upper reach of the All-American Canal from the Imperial Dam to the Pilot Knob Check should be considered for future study, pending agreement with the USBR concerning the amount of seepage underflow which returns to the Colorado River. The two lower reaches of the All-American Canal below Drop No. 1 fall short in the benefit/cost scale and should not be considered further unless the beneficial use of conserved water reaches a higher value.

2. Main Canals. Based on the results shown on Table 9-1, the East Highline Canal can beneficially be lined at this time, as can the Vail and Rositas Supply Canals. The Central Main Canal and Westside Main Canal should not be considered for lining until such time as the value of conserved water justifies such consideration.

3. Lateral Canals. There remain approximately 550 miles of laterals to be lined; however, it is estimated that it will be cost-effective to line only about 60% to 65% of that amount, or 350 miles. The benefit/cost analysis of lateral lining is based on this assumption. Assuming that 350 miles are lined, it is further assumed that the seepage loss is approximately 110 AF/year/mile (75% of the USBR estimate, see USBR, 1984b), or 38,500 AF/year. Assuming that 90% of the seepage can be conserved through canal lining, the net conservation is approximately 35,000 AF/year. Based on the results shown on Table 9-1, the lining of lateral canals is cost-effective and should be continued.

9.2.3 ENVIRONMENTAL CONSIDERATIONS

Canal lining would result in the cessation of water seepage. Although this seepage represents a significant loss of water from the irrigation system, it is necessary for the development and maintenance of wetland vegetation in the desert. Ponds and wetlands associated with canal seepage are concentrated along the Coachella, East Highline, and All-American Canals. The Coachella and East Highline Canals support the largest and highest quality wetlands.

Along the canals, riparian plant growth is typically restricted to a narrow zone approximately 3 to 15 ft wide immediately adjacent to the water's edge, while the levee berm and outer shoulder typically support vegetation influenced by adjacent community types. Therefore, a limited number of mammals are considered to be true associates of the canal/levee riparian community. The bypass channels that would be excavated would disrupt the current riparian habitats found along the canals. This could have an important impact on the wildlife utilizing this habitat. Of particular concern is the round-tailed ground squirrel commonly found along the slopes of the levee banks. This rodent plays an important role in the ecology of the burrowing owl (see subsection 6.4.1). The burrowing owl is currently classified as a Blue List Species (subsection 6.4.2) and only occurs in the canal/levee and agricultural/rural communities in the IID.

As discussed in subsection 6.4.1.B, there is a contrast in bird species composition between the wetter wetland areas having pockets of standing, open water and the more upland, less moist wetland areas. These contrasts provide insight into potential changes that would result from modification of water flow to seepage wetlands. Bird species associated with the less moist conditions would probably dominate if subsurface water flows were stopped.

During the fall and winter months, the canal/levee riparian community is used to a moderate extent by waterfowl species. Impacts affecting the quality of this community would place greater significance on the river riparian community, as well as on the wetland communities residing in the Salton Sea National Wildlife Refuge and Imperial Wildlife Area.

Wetlands provide habitats for three bird species listed as endangered and/or rare. These are the American Peregrine falcon, California black rail, and Yuma clapper rail (see Tables 6-23 and D-8). Clapper rails have also been sighted in canal/levee riparian communities. Figures 6-11 and 6-12 show the importance of wetlands for the Yuma clapper rail and the black rail.

The California Natural Areas Coordinating Council and the CDFG have identified a Creosote Bush Natural Area as an important natural area. It lies between the East Highline and Coachella Canals (see Figure 6-13). Creosote bushes in this natural area have attained unusual heights due to water seepage from the East Highline Canal.

As sections of the canals and laterals are lined, much of the aquatic biota will move out with the flow of water to other sections not currently being lined. As water is returned to the newly lined portions, many of these species may also return. It may be assumed that an overall change in the food web will result from changes in species composition and distribution in the aquatic environment.

Changes in water quality will probably be minimal, resulting in a slightly lower salinity in the water delivered. In addition, seepage to the Salton Sea would decrease.

Construction impacts in the lining of canals and laterals would be of a short-term duration. These impacts could include air quality, noise, transportation, and cultural resources.

9.3 CANAL COVERING

Covering of canals would reduce evaporation, and it is considered in this section. The methodology used was to select a representative canal and test for economic viability, extrapolating, if appropriate.

9.3.1 DESCRIPTION

Evaporation from uncovered water surfaces could amount to possibly 6 ft to 8 ft/year if the canal is full all year. If the lined canal were covered, such loss would be drastically reduced. In fact, a lined and covered canal might suffer total water losses comparable to pipelines. Furthermore, growth of plants would cease in the absence of light, and dust and debris would no longer enter the canal from above. These benefits are discussed in subsection 9.3.2.

Coverings of canals could be rigid or flexible. A rigid cover would require that the canal lining, or at least the upper part thereof, be itself rigid, i.e., concrete or soil cement. A flexible canal cover could be used with any type of canal lining.

Rigid canal covering could be in the form of precast concrete planks, precast concrete slabs, corrugated steel, steel planks, or steel decking. Any covering material would require support at the top of the canal lining, sealing of joints to prevent loss of evaporated water and/or entrance of solids from outside the canal, a method of placement with available equipment, and a method of removal (for canal maintenance) with available equipment. Another variable to be evaluated is the design load on the canal covering. As a minimum, rigid covering should safely carry the weight of personnel working on the covering. As a maximum, canal covering could be designed to carry several feet of earth cover, plus farm machinery, to permit farming within the canal ROW.

Flexible canal covering could be of a plastic sheet material, similar to plastic lining membrane, and would float on the contained water. Such flexible plastic coverings are used on several water reservoirs in California and elsewhere. Flexible covering, while weaker than rigid covering, is very inexpensive and might prove cost-effective in some cases.

9.3.2 BENEFITS AND COSTS

Lateral P, which is unlined, has been chosen as an example of possible benefits and costs of canal covering. When full, Lateral P has a water surface of approximately 39,600 ft by 6 ft, equaling 237,600 ft^2. Assuming that Lateral P is water-filled 90% of the year and estimating 6 ft/year evaporation from free-water surfaces, the annual water loss is approximately 29.45 AF/year. Covering Lateral P could, reasonably, conserve 90% of this evaporation, or 26.51 AF/year, worth $2,651. The total mileage of lateral canals as of December 31, 1984, was 1,445.19 miles (IID, 1985). Assuming that the average water surface width is 6 ft, that the average lateral is water-filled 90% of the time, and that canal covering conserves 90% of evaporation, then covering of all lateral canals would conserve:

$$\frac{(1{,}445.19\text{ mi})(5{,}280\text{ ft/mi})(6\text{ ft evap})(6\text{ ft wide})(0.90\text{ conserved})(0.90)}{43{,}560\text{ ft}^2/\text{AF}}$$

$$= 5{,}108\text{ AF/year}$$

Conserved evaporation would total 5,108 AF/year, worth $510,800 annually. The present worth of this amount over the 40-year life of the lining at the 8.125% discount rate of return used for these analyses is:

PW ($510,800; 8.125%; 37 out of 40 years)

PW factor = 9.1954773 = BPWF

$$= (510{,}800)\left[\frac{(1.08125)^{40}-1}{(0.08125)(1.08125)^{40}} - \frac{(1.08125)^{3}-1}{(0.08125)(1.08125)^{3}}\right]$$

$$= \$4{,}697{,}000$$

The project cost has been estimated at approximately $41.00/LF of canal to be covered. For Lateral P, the estimated cost of covering is $1,640,000.

Covering all lateral canals (assuming previous lining of all presently unlined lateral) is estimated to cost:

$$(1{,}445.19\text{ miles})(5{,}280\text{ ft/mi})(\$41.00/\text{lin ft}) = \$312{,}855{,}000$$

Annual O&M costs are estimated to be $44,200.

The present worth of the O&M cost is:

PW factor is 11.766773 = CPWF

PW = $44,200 (CPWF)
= $520,000

The total present worth of the cost is thus:

Capital cost =	$312,855,000
Annual cost =	520,000
Total	$313,375,000

The benefit/cost ratio for canal covering is therefore:

$$B/C = \frac{\$4,697,000}{\$313,375,000} = 0.015$$

Evidently, canal covering cannot be justified economically and will not be considered further.

9.3.3 ENVIRONMENTAL CONSIDERATIONS

Because only lined canals would be covered, the environmental concerns discussed in subsection 9.2.3 should have already been considered. Additional concerns would be the loss of water for wildlife species inhabiting the canal/levee riparian community. See subsection 9.2.3 for special-status species that would be affected. Covering the canals and laterals would eliminate the aquatic habitats now in existence. The desert pupfish, which is listed as endangered by the CDFG, used to be prevalent in this habitat but has drastically declined possibly due in part to competition from tilapia (CDFG, 1985). Construction impacts in the covering of canals would be of short-term duration and could include air quality, noise, and cultural resources.

9.4 PIPED DELIVERY SYSTEM

Replacement of unlined open lateral canals by piped irrigation water delivery systems would result in considerable water conservation, as well as other benefits, and is considered in this section. Again, a representative canal has been chosen as a prototype for analysis.

9.4.1 DESCRIPTION

Properly designed, constructed, maintained, and operated water piping systems lose very little or no water from leakage, and no water whatsoever from evaporation. Furthermore, water piping need not conform to hydraulic gradients but may drop considerably below the hydraulic grade line; the difference in elevation is the pipe's internal pressure. At present, there are very few stretches of piped delivery systems in the District. Most of the existing piping in the water delivery systems is in urban areas and in inverted siphons, e.g., the siphon carrying flow of the New Briar Canal under the All-American Canal. In addition, a few short stretches of piping exist in minor laterals where the adjacent farmer wished to farm within the irrigation canal ROW. As of December 31, 1983, the District listed 8.79 miles of pipelined lateral canal in service, over half of which was in the Brawley Division. The pipelined laterals in the Brawley Division are located in and near Brawley.

Pipelined irrigation canals are not only essentially leakfree but protect against entrance of silt and debris from above. However, silt and debris can enter pipelines from the entrance end and may be difficult to remove. Ideally, canals supplying pipelines should be lined to prevent erosion of canals, with subsequent washing of eroded material, plus plants and other debris, into the pipeline.

It is noteworthy that the Coachella Canal is concrete lined for a significant length and that the irrigation water distribution system in the Coachella Valley County Water District is entirely pipelined. Of course, Coachella is a much smaller district than is IID, with a much smaller and simpler irrigation system.

Pipelining drains in the District is well advanced, with a total of 113.27 miles of pipelined drains inventoried as of 1983. The pipelining has not been accomplished primarily to conserve water, but to save space, because open drainage ditches are generally very deep and, therefore, very wide at the top. The effects of pipelining drains are considered under sections 9.10, 9.11, and 9.12, as applicable.

Hitherto, pipelining irrigation water delivery systems in the District has invariably entailed the use of concrete pipe. Concrete pipe is cheap and locally available. However, it is not necessarily the optimum material in all cases. Concrete pipe is heavy, comes in short lengths, and is easily damaged at the ends unless expensive rubber-and-steel joints are used. The joints tend to leak unless rubber-gasketed joints (preferably rubber and steel) are used. In small sizes, plastic pipe materials can be unrolled from reels and placed by a deep plow, as is now done in the District with farm tile. Larger diameter high-density polyethylene pipe can be heat-welded into continuous pipelines as long as desired and dropped quickly into temporary, narrow trenches. Other plastic materials of interest are fiber-reinforced plastic, acrilonitrile-butadiene-styrene, and polyvinyl chloride. Each of these materials has certain applications for which it proves most cost-effective. Any one, or more than one, may be applicable in the District's conservation program.

9.4.2 BENEFITS AND COSTS

Lateral P, which is unlined, has again been chosen as an example of possible benefits and costs of a piped delivery system. When full, Lateral P has a water surface of approximately 39,600 ft by 6 ft, equaling 237,600 ft^2. Evaporation was shown in subsection 9.3.2 to be approximately 26.51 AF/year, worth $2,651. Seepage is estimated as 70 AF/mile/year for the remaining unlined lateral canal sections, based on USBR estimates, with a factor of safety of 2.

Lateral P has a length of 7.5 miles. The corresponding estimated seepage is 525 AF/year. Piping Lateral P would conserve 90% of the seepage, or 475 AF/year, worth $47,500. Assuming that approximately 550 miles of lateral will remain unlined at the initiation of the proposed project, total seepage is estimated as 60,000 AF/year. Pipelining would conserve 90% of this total, or 55,000 AF/year, worth $5,500,000 annually. This estimate is based on an assumption of 100 AF/year of seepage per mile of lateral or about 75% of the average for laterals used in the USBR Water Conservation Opportunities Report (USBR, 1984b).

The present worth of this amount over the 40-year life of the pipelines at the 8.125% discount rate used for these analyses is:

PW ($5,500,000; 8.125%; 37 out of 40 years)

PW factor = 9.1954773 = BPWF
= $5,500,000 (BPWF)
= $50,575,000

In addition, evaporation from 550 miles of open lateral would be conserved. Assuming that the average water surface width is 6 ft, that the average lateral is water-filled 90% of the time, and that pipelining would conserve 90% of the evaporation, then pipelining all laterals would conserve:

$$\frac{(550\text{ mi})(5{,}280\text{ ft/mi})(6\text{ ft evap})(6\text{ ft width})(0.90)(0.90)}{43{,}560}$$

= 1,944 AF/year, worth $194,400 annually

The present worth of this amount is:

$194,400 (BPWF) = $1,787,000

In addition, a considerable savings in maintenance costs would occur. Overall, it is estimated that if all unlined laterals were either lined or pipelined, maintenance of laterals would be decreased by two-thirds of the present expenditure. Assuming that maintenance is approximately 30% of O&M costs and that maintenance of unlined laterals takes 90% of the total maintenance expenditure, then pipelining 550 miles of laterals would decrease maintenance costs by approximately $2,000,000/year. The present worth of this amount is:

$2,000,000 (BPWF) = $18,391,000

Finally, pipelining would decrease the space currently required solely for irrigation water delivery. The area up to and over the irrigation pipeline could be formed. Conservatively, pipelining could return 0.5 acre/mile of land to productive use, 550 miles of pipeline would then return 275 acres to production. The present worth of this income would accrue to adjacent private landowners and is, therefore, not included herein.

Recapitulating, the present worth of benefits is:

Seepage conservation =	$50,575,000
Evaporation conservation =	1,787,000
Maintenance savings =	18,391,000
Total present worth	$70,753,000

The proportional present worth of Lateral P (length 7.5 miles) is:

$$\frac{(7.5)}{550}(\$70,753,000) = \$965,000$$

The cost of pipelining Lateral P has been estimated as $1,882,000. Assuming that other pipelines have a similar cost per mile, the overall capital cost of pipelining 550 miles of laterals will be $138,000,000. The estimated annual maintenance cost for 550 miles of pipelined laterals will be $1,920,000.

The present worth of this cost is:

$$\$1,920,000\ (\text{CPWF} = 11.766773) = \$22,592,000$$

Therefore, the total capital cost is:

$$\text{PW} = \$22,592,000 + \$138,000,000 = \$160,592,000$$

The benefit/cost ratio for pipelining unlined laterals is:

$$\frac{\$70,753,000}{\$160,592,000} = 0.44\ (\$227/\text{AF conserved})$$

On the whole, pipelining would not be cost-effective unless the value of conserved water exceeds $227/AF, which will normally be more expensive than lining. Therefore, pipelining will not be considered further except for unique cases, such as in urban areas where safety and aesthetics are more critical.

9.4.3 ENVIRONMENTAL CONSIDERATIONS

The installation of pipes for the delivery of irrigation water would result in the loss of the canal/levee riparian habitat and the elimination of all aquatic habitats in the canals. Impacts resulting from cessation of seepage as discussed in subsection 9.2.3 would also apply. In addition, more efficient delivery resulting from the installation of pipes may reduce the flow into the Salton Sea. During construction, excavation will most likely disrupt adjacent plant communities, while the movement of construction equipment through the area may have air quality, noise, and cultural resource impacts.

9.5 RESERVOIRS

At present, the District operates four regulating reservoirs and plans at least two more, as listed in section 4.1. For reasons given in that section, significant variations in flow can and do occur in the various canals. The four existing regulating reservoirs are the only means of reregulating canal flows. Their value both for water conservation and for improving on-farm operations is considerable.

The development of the District's water conservation plan will almost certainly entail additional regulating reservoirs on the main canal system. In addition, one or more large regulating reservoirs may be desirable on the All-American Canal to smooth out the sometimes severe fluctuations in water surface elevations and flow rates in this long canal. However, perhaps the most important from the standpoint of improving service and, simultaneously, conserving water is an array of small reservoirs dispersed on laterals throughout the system. That is the alternative considered in this section.

9.5.1 DESCRIPTION

The system envisioned would consist of approximately 135 10-AF-capacity reservoirs. Each would be located near the mid-section of a lateral. The concept of operation would be for the District's zanjeros to divert excess water, on request of a consumer, from the lateral into the reservoir to hold for use by a grower who needs more water that day or to use the next day by reducing the next day's order by the amount held in storage. The reservoirs would have extreme fluctuations in the daily amount held in storage, probably going from full to empty daily. As such, there would be few advantages to wildlife; however, dramatic reductions in tailwater and operational losses could be expected.

The number of reservoirs was estimated by first assuming one reservoir for every 8 miles of lateral:

$$\frac{1{,}445.19 \text{ miles}}{8 \text{ miles}} = 180.65$$

It was determined on examination of the IID system that approximately 25% of the laterals were too short to make effective use of a reservoir or had some other drawback that precluded full exploitation. Therefore,

$$180.65 \times 0.75 = 135 \text{ reservoirs}$$

The 135 reservoirs calculated as just described would, in some cases, be located at drops to take advantage of gravity inflow and outflow, but would, in other cases, require a pump station to put stored water back into the lateral. Therefore, two basic reservoir prototypes were defined:

Gravity Flow	Pumped Flow	Total
70	65	135

Each prototype had the following characteristics:

(1) Total area required: 2.2 acres (includes O&M access)
(2) Lining + side walls: soil-cement
(3) Depth: 6 ft, plus 2-ft freeboard
(4) Security: chainlink fence

(5) Capacity: 10 AF (average)
(6) Facility life: 40 years

The capacity of the prototype was based on:

$$20\ ft^3/sec \times 6\ hours = 10\ AF$$

The capacity represents about 10% to 15% of the capacity of a large lateral and about 25% of an average lateral's daily flow. This should be sufficient to cover all but abnormal fluctuations.

9.5.2 BENEFITS AND COSTS

The benefit of the reservoirs is a reduction in both tailwater and operational discharge. It is conceivable that a reservoir system could eliminate all of these losses; however, in practice this is not expected. For example, there may be times when a reservoir is filled one day and nobody orders any water downstream of the reservoir for the next month. Such cases are expected to be rare, but possible. Moreover, the farmers will still occasionally overestimate their needs and the water will be ponding on-farm before anyone reacts. These factors were considered in arriving at the following estimates for water conservation resulting from a reservoir program:

Conservation Category	Estimated Amount Conserved (AF/year)
Reduction of operational discharge	22,000 (25% of 88,000)
Reduction of tailwater	13,500 (5% of 270,000)
Total	35,500
Use	35,000

The monetary benefit from the program would therefore be:

B = 35,000 AF/year x $100/AF = $3,500,000/year

The present worth of this amount over the 40-year life of the reservoir at the 8.125% rate of return used for these analyses is:

PW (3,500,000; 8.125%; 37 out 40 years)
= $3,500,000 (BPWF)
= $32,184,000

The project cost is derived as,

Unit capital cost of gravity flow reservoir = $131,000
(including engineering, construction management, and land)

Unit capital cost of pumped flow reservoir = $137,000
(including engineering, construction management, and land)

Therefore,

Total capital cost = 70 x $131,000 + 65 x $137,000
= $18,075,000

Annual O&M and other service costs are estimated to be:

Unit annual O&M cost gravity flow reservoir = $4,000/year (x 70)

Unit annual O&M cost pump flow reservoir = $7,000/year (x 65)

Total annual O&M = $735,000

The present worth of the O&M cost is:

PW ($735,000; 8.125%; 40 years)
= $735,000 (CPWF)
= $8,649,000

The total present worth of the cost is thus:

Capital cost =	$18,075,000
Annual cost =	8,649,000
Total	$26,724,000

The benefit/cost ratio for the reservoirs is:

B/C = $32,184,000/$26,724,000
= 1.20 ($83/AF conserved)

The ratio appears to be satisfactory and the reservoirs certainly merit further consideration. Sensitivity analyses for this alternative indicate that if benefits were overestimated by 50%, the benefit/cost would still be greater than unity.

9.5.3 ENVIRONMENTAL CONSIDERATIONS

A. Terrestrial Biology

The construction of reservoirs would remove terrestrial habitat. Certain areas of special biological significance should be avoided such as wetlands, areas supporting threatened or endangered species, and other important natural areas. Wetlands of Imperial County (Figure 6-6) are located along the All-American Canal near Drops Nos. 2 and 4, along the East Highline Canal near Highway 78, and along the section east of Niland to east of Calipatria. Additional wetlands are located at the Salton Sea National Wildlife Refuge and the Finney Ramer, Wister, and Hazard Units of the Imperial Wildlife Refuge.

Threatened, rare, and endangered species are listed in Table 6-23, including six species of birds that occur in the IID. The Yuma clapper rail and the black rail are the most vulnerable because they inhabit the wetland area east of the East Highline Canal where it crosses the All-American Canal between

Drop Nos. 4 and 5 (Olech, 1985). Two reptiles and one plant are also listed in Table 6-23, but their habitats appear to be far enough away from the canals and drains that they would not be impacted by reservoirs.

Other important natural areas, designated by the California Natural Areas Coordinating Council and the CDFG (subsection 6.4.2.C), are the Salton Sea National Wildlife Refuge and associated wetlands, the Imperial Wildlife Area, and the Creosote Bush Natural Area. Figure 6-13 shows the locations of these areas. A potential for reservoir impact exists at the giant creosote bush area shown in Figure 6-13 between the East Highline and Coachella Canals due east of Calipatria. The Algodones Dunes are also an important natural area located just east of the Coachella Canal outside of the IID boundary.

Terrestrial habitat destruction could be mitigated by the creation or expansion of riparian habitat around the reservoirs as a tradeoff. Riparian habitat is scarce in the Imperial Valley, and the creation of new riparian habitat should be beneficial. The value of the terrestrial habitat to be removed must be weighed against the value of the riparian habitat to be created. If important terrestrial habitats are not destroyed, reservoir construction should be environmentally acceptable.

Reservoirs would help smooth out the fluctuations in water level along major canals. Present fluctuations in water level create a zone that is neither aquatic nor riparian. By smoothing out water-level fluctuations, aquatic and riparian habitats could be expanded below and above the more stable waterline.

B. Aquatic Biology

As just discussed, reservoirs would help smooth out the fluctuations in water level along major canals and would expand both aquatic and riparian habitats below and above the more stable waterline. The reservoirs would provide for more shoreline habitat for aquatic plants and benthic macroinvertebrates. Reduced maximum flows could reduce scour and enable more growth of aquatic plants, benthic macroinvertebrates, and plankton.

Reservoirs would create aquatic habitats with slower moving water suitable for primary production. They would also provide fish breeding areas and would help strengthen the canal fisheries. In general, reservoirs would provide aquatic habitats that would increase the biomass of the canal system and would create a more natural environment of alternating fast- and slow-moving waters, which would aid in the survival of existing species.

C. Water Quality

The addition of reservoirs should have negligible impacts on water quality. At a minimum, salinity could increase slightly from increased evaporation in the reservoirs.

D. Salton Sea

Decreased fluctuations in flow will result in water conservation because waste resulting from flows greater than expected will be reduced. This would result in decreased flow into the Salton Sea, thus decreasing dilution and increasing salinity.

E. Other Considerations

Other environmental considerations regarding reservoirs are the possible construction impacts and land-use conflicts. Construction impacts could include fugitive dust and particulate air emissions, noise, transportation impacts, cultural resource impacts, and others. These impacts would be of short-term duration and should not adversely impact the environment unless construction were to take place in an environmentally sensitive area.

Because most of the land surrounding canals and laterals is used for agriculture, reservoir construction could encroach onto agricultural lands. Loss of land for agriculture could, therefore, be an adverse impact that should be minimized.

9.6 IMPROVED FARM DELIVERIES

9.6.1 DESCRIPTION

Since the 1940s, farm delivery structures have been installed or reconstructed to standard designs. The farm delivery structures are concrete; aluminum gates are secured in position by pins through holes in the gate hoist and over the frame built into the farm delivery box. In this method of operation, the zanjero first adjusts the nearest downstream lateral or canal check gate to establish a predetermined water surface elevation in the canal or lateral. He then raises the farm gate in accordance with flow rate versus gate setting tables, and pins the farm gate in place. The farm gates appear to be well thought out and are generally in good repair.

However, because of difficulties in flow routing, the water surface at the farm gate may vary from that intended. Furthermore, surges from outside of the zanjero's area of responsibility may run down a main canal, causing canal or lateral inflow to deviate from that programmed by the hydrographer. Finally, the on-farm irrigation operation may create a variation in the hydraulic conditions at the delivery outlet that will cause inflow to vary.

Means must be developed, programmed, and implemented to minimize these variations in flow rate. If the water flow rate and surface elevation in the canal or lateral vary measurably, then the delivery rate to the farm will not be as planned. It would be physically possible to replace the farm gates with self-regulating gates and/or weir control structures that compensate for variations in the upstream and downstream water surface elevation. An evaluation of such structures should be made; however, it appears at this time that closer regulation of canals and laterals using other measures discussed in this report would achieve comparable results, more reliably. This is because maintenance of several thousand individual farm deliveries would be much more complicated than maintaining other delivery system components that control the hydraulic reaction of the system.

It is noted that farmers, being conservative businessmen, will make allowances for possible flow variations by ordering more water than actually needed. If the accuracy of flow deliveries were improved, farmers would probably decrease their margin-of-error allowance and order less water; however, the degree to which this would occur would probably be masked by many of the other measures discussed in the report.

9.6.2 BENEFITS AND COSTS

The O&M and maintenance problems predicted for self-regulating farm deliveries tend to make this alternative lower in priority than several other measures. Nevertheless, this concept is recommended for continued evaluation in routine IID programs, and it is to be studied while other conservation measures are applied for maximum effect. At a future date, a more ambitious effort could be undertaken.

9.6.3 ENVIRONMENTAL CONSIDERATIONS

The end result of installing new farm delivery boxes and meters would be a minor decrease in flow through the canal system as a result of water conservation. More stabilized flow in larger canals and laterals with smaller fluctuations in water level would create more aquatic and riparian habitat below and above the waterline. Reduced maximum flows would reduce scour and enable more growth of aquatic plants, benthic macroinvertebrates, and plankton.

The salinity in the Salton Sea would increase as a result of decreases in flow. Lower flow into the Salton Sea would decrease the amount of dilution water, causing salinity to rise faster than at the present rate.

Construction impacts such as fugitive dust, particulate air emissions, noise, and cultural resource impacts would be incurred, but they are expected to be insignificant. Farm delivery boxes and meters are small and require little construction activity. Encroachment onto agricultural lands should not be a problem because construction activities should stay within the IID ROWs.

9.7 IMPROVED FLOW-MONITORING STRUCTURES

The District's method of measuring flow in canals and laterals is reasonably accurate and is more than adequate for water routing and billing purposes. Nevertheless, the IID has recognized (IID Water Conservation Plan, 1985) the need to upgrade the accuracy of these measurements in order to locate and substantiate water lost in various ways and water conserved through District programs. The objectives of the measure are:

(1) More efficient water routing with attendant water conservation.

(2) Accurate determination of water conserved in the overall system through the various conservation measures instituted by the IID.

This measure may eventually be expanded to include improvements in monitoring inflow and outflow at each farm delivery and outlet in order to allow efficient water users to be recognized and possibly rewarded through incentive programs (discussed in Chapter 10). This concept will be studied further during the implementation phase of the conservation program.

9.7.1 DESCRIPTION

The program envisioned is to install approximately 1,500 metering/recording stations throughout the District, measuring inflow in every lateral, outflow of every IID drain, and selected key intermediate points throughout the system. Each structure would consist of a meter that is calibrated to measure flow to within ±5% of actual flow and to continuously record the results. This will be more accurate than now possible, not so much because of instantaneous readings but because of the continuous recording that can be integrated to arrive at total flow for a day, week, etc.

9.7.2 BENEFITS AND COSTS

The benefit from this program is impossible to rigorously define; however, it is conservative to allot a 10% savings of the loss estimated for tailwater and operational discharge:

Water conserved = 0.1 x (270,000 AF/year + 88,000 AF/year)
= 35,800 AF/year
use 36,000 AF/year

Therefore, benefits are:

B = 36,000 AF/year x $100/AF
= $3,600,000/year

The present worth of these benefits is:

PW ($3,600,000; 8.125%; 37 out of 40 years)
= $3,600,000 (BPWF)
= $33,104,000

The cost of the program is estimated to be:

Unit cost of meter/recorder = $4,000 (life = 5 years)

For 1,500 installations = $6,000,000 (every 5 years)

Capital cost = $17,741,000 (initial cost + present worth of following 7 payments)

The annual O&M and other service costs are estimated to be:

Annual O&M cost = $1,000,000 (including extra zanjeros and technicians)

The present worth of the O&M cost is:

PW (1,000,000; 8.125%; 40 years)
= $1,000,000 (CPWF)
= $11,767,000

The total cost is therefore:

Capital cost =	$17,741,000
Annual O&M cost =	11,767,000
Total	$29,508,000

The benefit/cost ratio for the improved monitoring structures is:

B/C = $33,104,000/$29,508,000 = 1.12 ($89/AF conserved)

This value of the benefit/cost ratio qualifies this water conservation measure for further consideration. Moreover, improved flow monitoring is essential to the accurate determination of conserved water. Therefore, this measure must be implemented very early in the overall conservation program to verify that water savings are occurring.

9.7.3 ENVIRONMENTAL CONSIDERATIONS

Improved flow-monitoring structures are designed to more efficiently regulate the flow of water through the canal system. As a result, less water would be spilled into the drains as tailwater and operational discharge. The environmental considerations are essentially the same as those described in subsection 9.9.3. Both conservation methods ultimately reduce the flow through the New and Alamo Rivers and into the Salton Sea. However, improved flow-monitoring structures would cause less new ground disturbance because these structures would be located entirely within existing canals. It is assumed that the improvements to flow-monitoring structures would take place in lined canals or as part of a canal lining program. Other environmental factors are discussed in subsection 9.9.3.

9.8 NONLEAK GATES

In the early days of the District, wooden gates were installed throughout the irrigation system as turnout headgates, canal checks, lateral checks, etc. The gates were loosely fitted into slots cast into the concrete or masonry gate structures. Gates were usually raised or lowered by jacking against a wood frame. Wood, when alternately wet and dry, invariably deteriorates. Many of the wooden gates still in service leak so much that nominally dry laterals sometimes carry a visible water current.

9.8.1 DESCRIPTION

The District has undertaken a long-term program for replacing the deteriorated wooden gates with aluminum slide gates. Neither the gates nor the gate slots are uniformly standardized, reflecting, perhaps, their installation as funding became available. Many of the aluminum gates appear reasonably watertight.

Others, especially those fitted into old, deteriorated structures, do not hold water as well as might be expected and are, therefore, not nonleak gates. The old, wide slots originally designed for wooden gates are difficult to rework in order to receive aluminum gates correctly. Under the circumstances, the District has done a commendable job in reducing leakage through the system's gates.

The contemplated program entails the following steps:

(1) Complete standardization of design of aluminum gates (including aluminum frames, if necessary) and gate-slot modifications at existing adequate structures.

(2) Complete standardization of design of replacement concrete structures, where existing structures are excessively deteriorated.

(3) Rapid replacement of remaining wooden gates and structures, where necessary.

(4) Backchecking of all previously installed aluminum gates, making necessary modifications/repairs to bring installations up to the performance expected of nonleak gates.

9.8.2 BENEFITS AND COSTS

The benefits to be expected from installation of nonleak gates throughout the irrigation system are a 15% conservation of operational discharges and a 5% conservation of tailwater:

Water conserved = 0.15 (88,000 AF/year) + 0.05 (270,000 AF/year)
= 26,700 AF/year
use 27,000 AF/year

Therefore, benefits are:

B = 27,000 AF/year x $100/AF
= $2,700,000/year

The present worth of these amounts over the 40-year return used for these analyses is:

(BPWF) ($2,700,000) = $24,828,000

There are at present 326 lateral headgates and 3,173 lateral checks installed, for a total of 3,499 gates installed in lateral systems (exclusive of farm delivery gates). Some of the headgates and checks are multiple gates. The total number of gate leaves in place is about 3,600, of which about 60% leak enough to need replacement. The number of gates to be replaced with nonleak gates is thus estimated at 2,160. The estimated cost per gate installation is $660 for a total capital cost of $1,425,600. The estimated annual incremental maintenance cost for 2,160 leakproof gates is $100,000. The present worth of this amount over the 40-year life of the gates at the 8.125% rate of return used in the analyses is:

(CPWF) ($100,000) = $1,177,000

Therefore, the total capital cost is $1,425,600 + $1,177,000 = $2,602,600

The benefit/cost ratio for installing leakproof gates is:

$$\frac{\$24,828,000}{\$2,602,600} = 9.54 \text{ (\$10/AF conserved)}$$

On the whole, installation of nonleak gates throughout the system should be very profitable.

9.8.3 ENVIRONMENTAL CONSIDERATIONS

The environmental considerations of the installation of nonleak gates are associated primarily with the loss of aquatic and terrestrial habitats and the reduction of flows to the Salton Sea. Ground disturbance associated with the construction of these gates is assumed to be small; thus, the construction impacts such as air emissions, noise, and impacts to cultural resources would be small.

Leaking gates currently maintain a number of essentially perennial aquatic habitats and create riparian habitats through the growth of phreatophytes. In other areas, leaking gates result is little or no new habitat, but they result in spills into the drains. The degree of environmental effect is dependent on several factors:

(1) Location of the gate within the IID system.

(2) Rate at which water is leaking.

(3) Condition of the canals on the downstream side of the leaking gate (i.e., lined or unlined).

Leaking gates located at the lateral turnout may create aquatic habitats by maintaining a small, continuous flow through the lateral. The quality of the stream depends on whether the lateral is lined or unlined. Unlined canals will support a more diverse biotic community that is more resistant to fluctuations in flows as water is delivered. This habitat is probably of minor consequence in terms of supporting a fishery because the volume and flow rates are small. It may, however, provide a riparian habitat that supports wildlife. These habitats would be lost in the course of installing nonleak gates.

Terminal leaking lateral check gates may result in operational spills into the drainage system. Water diverted to drains would result in a slight increase in flows to the New and Alamo Rivers and ultimately to the Salton Sea. Thus, replacing these gates would cause a slight decrease in flow to the Salton Sea.

Leaking lateral check gates contribute to operational spills that ultimately flow into the drains. The degree to which leaking check gates contribute to operational spills is unknown at this point, but it is probably minor in comparison to that caused by uncontrolled fluctuation of flow through the laterals. Nevertheless, replacement of these gates would cause a reduction in flow through the drainage system. Impacts associated with this reduction would be a slight increase in salinity in the New and Alamo Rivers and, ultimately, a decreased flow to the Salton Sea. The degree to which this effects the level or salinity of the sea requires further analysis.

9.9 RECOVERY OF OPERATIONAL DISCHARGES

Mismatches between water delivery rates as ordered and as delivered often result in unwanted water reaching the end of a canal or lateral, where it must be discharged. These discharges will continue even after the complete replacement of all wooden gates with metal gates, further automation of flow controls, and installation of additional regulating reservoirs. Human error, adverse weather conditions, and equipment malfunction can never be completely eliminated. Therefore, a system for recovery and reuse of operational discharges would be beneficial.

9.9.1 DESCRIPTION

The District currently plans a study of such a system (IID Water Conservation Plan, 1985):

> "The District plans to study, design, and construct a pilot spill interceptor system. After construction, evaluation will be made and, if warranted, design of a full-scale system will be initiated. This pilot program will evaluate the effects that a spill interceptor system will have on lateral spill, operational flexibility and tailwater discharge. Five laterals have been identified as the study area (Exhibit VI.7), located in the East Highline Canal system. Spill currently flows into the Alamo River. Both spills and drains in the study area will be measured to obtain baseline data for comparison with data gathered after construction of the interceptor system. Final design of the facilities and construction will begin in 1986."

The study presented here evaluates the economic feasibility of such a system, except that the area proposed by the District was expanded to include all the laterals from Palmetto Lateral on the south to the Vail Supply Canal on the north. The model used in this study consists of a canal that would be constructed to intercept the spills at the end of each lateral and convey these flows to a collector reservoir adjacent to the Vail Supply Canal. At each lateral intersection with the interceptor canal, a standard gated check structure is provided to maintain sufficient water surface elevation for deliveries to farms downstream from the lateral end. A piped siphon is thus provided to convey farm deliveries under the interceptor canal to farms on the other side. All spills from the laterals into the interceptor canal would be through the end check structure, which would act as a weir for measuring purposes. All collected spill flows, up to the maximum capacity of the interceptor canal, would be conveyed north to a 50-AF collector reservoir. A

Parshall flume is provided for intake to the reservoir and a gated structure for outlet into the Vail Supply Canal, which is regulated from the existing Singh Reservoir. The interceptor canal is approximately 22.8 miles long and would collect spill from an area approximately 20% of the IID.

9.9.2 BENEFITS AND COSTS

The benefit to be gained from this facility would be conservation of the operational discharge that occurs in the area served. Because the prototype system serves about 20% of the IID, it is assumed that a commensurate amount of conservation is possible, i.e., 20% of the 88,000 AF/year attributed to operational discharge, or approximately 17,600 AF/year. However, an added benefit would also occur. Were such a system in place when a farmer determines that he has enough irrigation water before his run is complete, he could have his delivery closed and the excess water routed to the operational discharge recovery system. This would be in lieu of the present condition when the excess water is routed onto the farm to become tailwater. It is estimated that 20% of the tailwater now experienced could be conserved if the subject system existed, a savings in the case of the prototype system of 10,800 AF/year (0.2 x 270,000 AF/year x 0.2 = 10,800 AF/year). The total amount conserved would then be:

$$
\begin{aligned}
0.2 \times 88{,}000 \text{ AF/year} &= 17{,}600 \text{ AF/year} \\
0.2 \times 0.2 \times 270{,}000 \text{ AF/year} &= \underline{10{,}800} \text{ AF/year} \\
\text{Total} \quad & 28{,}400 \text{ AF/year}
\end{aligned}
$$

Assuming a 400-AF/year loss to evaporation, the net conservation is 28,000 AF/year, or a benefit of:

$$
\begin{aligned}
B &= 28{,}000 \text{ AF/year} \times \$100/\text{AF} \\
&= \$2{,}800{,}000/\text{year}
\end{aligned}
$$

$$
\begin{aligned}
PWB &= BPWF \times \$2{,}800{,}000 \\
&= \$25{,}747{,}000
\end{aligned}
$$

The estimated capital cost of the prototype system is $10,400,000. The estimated annual O&M cost of the prototype system is $200,000, which has a present worth of:

$$\text{O\&M PWC} = (\text{CPWF})\ (\$200{,}000) = \$2{,}353{,}000$$

The total present worth of costs is therefore:

$$CPW = \$10{,}400{,}0000 + \$2{,}353{,}000 = \$12{,}753{,}000$$

The benefit/cost ratio for the prototype system is thus:

$$B/C = \frac{\$25{,}747{,}000}{\$12{,}753{,}000} = 2.02 \ (\$50/\text{AF conserved})$$

This analysis predicts a strong economic justification for such a system. Assuming that the system can be applied in other areas, it appears reasonable to expand the use of this concept. It is estimated that at least another 20% of the IID could be profitably exploited, as defined in this section, swelling the total water conservation to:

Operational discharge conserved =	34,000 AF/year
Tailwater conserved =	22,000 AF/year
Total conserved	56,000 AF/year

9.9.3 ENVIRONMENTAL CONSIDERATIONS

The recovery of operational discharge water would result in reduced flow into the IID drainage system. This reduced flow would ultimately result in lower flows through the New and Alamo Rivers and into the Salton Sea.

Operational discharges represent water with relatively low salinity. The loss of this water in conjunction with the continued high salinity drain water would result in higher salinity in the New and Alamo Rivers and also in the Salton Sea. The New and Alamo Rivers are already brackish water habitats with salinities of typically 3,000 to 4,000 mg/L. The degree to which recovery of operational discharges would increase the salinity is dependent on the volume of operational spills that could be recovered. The increased salinity would potentially cause ecological effects on the aquatic biota of the New and Alamo Rivers. However, the total present operational losses are small in comparison to the total drainage flow. As shown in Table 5-5, operational discharges for 1982 through 1984 averaged approximately 89,000 AF/year in comparison to a total surface outflow of 1,109,000 AF/year. If 100% of this discharge is conserved, the ultimate increase in salinity in the New and Alamo Rivers would be less than 10% of the current salinity levels, which a great enough increase to cause a change in the aquatic biology of these rivers.

The effect of recovery of operational discharge on the Salton Sea would be a slight decrease in the inflow to the sea. The actual effect on the level of the sea depends on the overall water balance in the future. The decreased flow will contribute to either a lowering of the elevation or a slowing in the rise of elevation. Although a slight decrease in salt input to the sea would probably be a result of this water conservation method, the overall salt loading would remain high, thus continuing the increase in salinity. The decrease in flow may slightly increase the rate of salinity rise by decreasing the flow of dilution water. This effect is small, however, in comparison to the overall change in salinity expected in the Salton Sea.

Recovery of operational discharges requires construction of spill interceptors or other structures that would require the examination of potential impacts to cultural resources. However, these impacts are expected to be minor because most construction will probably occur within a previously disturbed ROW.

9.10 TAILWATER RECOVERY

To date, most references to a tailwater recovery system have meant an on-farm system run by a farmer. This section presents a different concept.

9.10.1 DESCRIPTION

The idea discussed here is to intercept all tailwater outlet pipes with a tailwater collector pipe in the existing open channel drains. Water in these collectors would flow by gravity to the end of the drain into a collector main that would accept flow from a series of such collector laterals. These mains would eventually terminate in water treatment facilities where it would be treated and pumped back to an appropriate point in the delivery system.

To calculate costs, a prototype system was defined, consisting of 35 8-mile-long drainpipes at 4,000-ft intervals located in existing IID drains. These drains feed a main collector 28 miles long, terminating in a 40-MGD treatment plant. An 8-mile-long force main will pump the plant effluent to a main supply canal for reuse of the tailwater. This system is programmed to serve approximately 20% of the District and it is therefore assumed, for benefit/cost analysis, that 54,000 AF/year of water will be conserved out of an estimated total of 270,000 AF/year. It is also assumed that additional systems could be installed throughout the IID, swelling the total to about 90% of tailwater or approximately 243,000 AF/year.

9.10.2 BENEFITS AND COSTS

The benefits obtainable from this measure are the water conserved at $100/AF:

B = 54,000 AF/year x $100/AF
= $5,400,000/year

The present worth of these benefits is:

PW ($5,400,000; 8.125%; 37 of 40 years)
= $5,400,000 (BPWF)
= $49,656,000

The capital costs of the system are:

Collector system =	$ 84,000,000
Treatment plant =	24,000,000
Force main =	15,000,000
Total	$123,000,000

The O&M costs (including power) are estimated at $750,000/year.

The present worth of these costs is:

PW (750,000; 8.125%; 40 years)
= $750,000 (CPWF)
= $8,825,000

The total present worth of costs is:

Capital costs =	$123,000,000
Annual costs =	8,825,000
Total	$131,825,000

The benefit/cost ratio for this system is thus:

B/C = $49,656,000/$131,825,000
= 0.38 ($265/AF conserved)

This benefit/cost ratio is not competitive with those of other measures, and this concept will not be included in the program defined later.

9.10.3 ENVIRONMENTAL CONSIDERATIONS

Tailwater recovery generates a significant quantity of water that could be returned to farmers for reuse. For this analysis, it is assumed that this water would not be treated, but simply mixed with incoming supply water and reused. The end result would be a reduction in the quantity of canal water delivered to the farmer, which would not be a one-for-one reduction because the tailwater has somewhat higher salinity than the supply water. Thus, the leaching requirements would be slightly higher.

The net effect of tailwater recovery is a reduction in flow to the drainage system and a corresponding increase in salinity. This effect would result in a significant decrease in flow to the Salton Sea. The salt loading would remain high. Thus, the Salton Sea could experience a decrease in elevation. The salinity of the sea will continue to rise, and eventually will affect the survivability of the Salton Sea biota. The salinity in the New and Alamo Rivers will probably increase, but not significantly in terms of altering the aquatic ecology.

9.11 LEACH WATER RECOVERY

An estimated 280,000 AF of leach water is used annually in the IID. Separate leach water recovery systems are discussed as follows.

9.11.1 DESCRIPTION

Leach water is found throughout the IID occurring at the lower end of each field that is equipped with a tile drain systems. At a number of these locations where leach water systems are lower than the adjoining District drain systems, pump sumps are already in place. Leach water does not occur as a steady flow but tends to occur as a peak flow following each irrigation, slowly decreasing over several days.

Samples of the quality have been taken of leach water for a number of years. This water tends to average 6,000 mg/L of TDS; therefore, the system tested in this report uses a reverse-osmosis treatment plant to reduce salinity to an acceptable level.

The system selected for evaluation is very similar to that used in section 9.10. The only difference is that the treatment facility will be a reverse-osmosis unit, and the pipe will be placed in the bottom of IID drains rather than on supports 2 ft off the bottom.

9.11.2 BENEFITS AND COSTS

The benefit in this case will be 20% of the total 280,000 AF/year of leach water, or 56,000 AF/year at $100/AF:

B = 56,000 AF/year x $100/AF
= $5,600,000/year

The present worth of this benefit is:

PW (5,600,000; 8.125%; 37 of 40 years)
= $51,495,000

The capital cost of the facility is estimated as follows:

Collector system =	$ 84,000,000
40-MGD desalination plant =	56,000,000
Force main =	15,000,000
Total	$155,000,000

The O&M costs for the system are expected to be about $8,760,000/year with a present worth of:

PW ($8,760,000; 8.125% 40 years)
= $8,760,000 (CPWF)
= $103,077,000

The total cost is:

Capital cost =	$155,000,000
O&M =	103,077,000
Total	$258,077,000

The benefit/cost ratio is thus:

B/C = $51,495,000/$258,077,000
= 0.20 ($501/AF conserved)

This indicates that conserved water must be valued at over $500/AF to make the project economically viable. It is estimated that 80% of the leach water could be conserved with this method, if applied, for a total of 224,000 AF/year.

9.11.3 ENVIRONMENTAL CONSIDERATIONS

The environmental considerations associated with leach water recovery are similar to those discussed in subsection 9.10.3 for tailwater recovery. The major difference is the much higher salinity concentration of the leach water. If recovered leach water is blended directly with incoming canal waters, it must be diluted significantly, and a greater quantity of blended water must be used to meet the leaching requirements. The end result would be a reduction in net water consumption and flow into the drains. The salt loading, however, would continue to be high. Increases in salinity of the New and Alamo Rivers would be expected. However, without a sizable reduction in flow, this increase would probably not cause any changes in the aquatic biota. The current leach water flow is estimated at 250,000 to 300,000 AF/year. This quantity may be large enough to lower the level or reduce the rate of increase in the level of the Salton Sea. The salinity of the sea will continue to remain high.

The alternative uses of leach water would be to desalinate prior to municipal or agricultural reuses. The additional impacts that should be considered are those discussed in section 9.5. These issues include the affects of brine disposal on the terrestrial and aquatic communities. Most of the affects would probably be on the terrestrial environment.

9.12 DRAIN WATER RECOVERY

Drain water is available throughout most of the IID service area. Drain water is primarily composed of water derived from tailwater and leach water from farm operations and from canal discharges and seepage from the District's operations. Stormwater is also collected by the drainage system, and in some of the drains there is sewage flow.

The quality of drain water varies depending on the relative quantities of different sources available. In general, the quality of drain water has a TDS content of approximately 3,500 mg/L.

Under current IID policy, drain water is available for use at no charge to the user. Currently, drain water is only being used for irrigation of some duck ponds and wildlife enhancement areas and as inflow for recreational reservoirs. Growers are reluctant to use drain water for irrigation because of increased salinity and unknown quantities of pesticides and herbicides entering from other fields. Beneficial use of drain water at the present time is to maintain salinity control in the Salton Sea.

9.12.1 DESCRIPTION

Inflow into the drainage system based on the data in Chapters 5 and 7 is estimated at 900,000 AF/year. In general, better quality drain water can be obtained directly from the drains prior to the time that they enter the New and the Alamo Rivers. Uses that could be made of drain water include the following:

(1) Irrigation of wildlife lands
(2) Lake makeup water
(3) Industrial use, primarily cooling water at geothermal plants
(4) Direct irrigation of farm lands
(5) Municipal use following reverse-osmosis treatment

The system synthesized for economic analysis consists of the main collector pipeline designated in the two previous sections that collects the entire drainage flow into the IID drains. Therefore, no laterals collectors are needed.

The other system components are a reverse-osmosis treatment plant and a force main, as discussed in sections 9.10 and 9.11.

9.12.2 BENEFITS AND COSTS

The benefit for this prototype will be based on the total of tailwater and leach water used in sections 9.10 and 9.11, or:

Tailwater =	54,000	AF/year
Leach water =	56,000	AF/year
Total	110,000	AF/year

B = 110,000 AF/year x \$100/AF
= \$11,000,000/year

The present worth is:

PW (\$11,000,000; 8.125%; 37 of 40 years)
= \$11,000,000 (BPWF)
= \$101,150,000

The cost estimate is:

Collector system =	\$ 21,000,000
80-MGD desalination plant =	100,000,000
Force main =	17,000,000
Total	\$138,000,000

The O&M costs for the system are estimated at \$16,400,000/year with a present worth of:

PW (\$16,400,000; 8.125%; 40 years)
= \$16,400,000 (CPWF)
= \$192,975,000

The total cost is:

Capital cost =	\$138,000,000
O&M =	192,975,000
Total	\$330,975,000

The benefit/cost ratio is thus:

B/C = \$101,150,000/\$330,975,000
= 0.31 (\$327/AF conserved)

Not surprisingly, this is essentially the same result as for the tailwater system and would also require conserved water valued at over $300/AF.

9.12.3 ENVIRONMENTAL CONSIDERATIONS

Drain water represents a combination of leach water, tailwater, operational discharges, and groundwater underflow. It has salinity that is intermediate between the high salinity leach water and lower salinity tailwater and groundwater. Water in the New and Alamo Rivers also contains municipal and other miscellaneous effluents, as well as inflow from Mexico. Reuse of drain water would reduce flows through the New and Alamo Rivers. This reduction in flow may be significant if a large enough quantity of drain water is used. Impacts could occur to areas such as the Finney-Ramer Wildlife Unit on the Alamo River. These lakes could experience a drop in level if enough flow is removed from the system.

Potential beneficial uses of drain water include the irrigation of wildlife lands. This use is already occurring. Any future increased use would necessitate expansion of wildlife management areas.

The expanded reuse of drain water would also result in higher salinity concentrations in the New and Alamo Rivers. With very high reuse, the salinity could increase to the point where stress was placed on the existing aquatic biota. It does not seem likely that the salinity would increase to such an extent that changes in species composition would occur.

Reuse of drain water could include desalination prior to use, which could create additional impacts by creating a need for brine disposal areas. These areas would probably be created either by removing agricultural land from production or by destroying an area of terrestrial habitat. With careful selection of disposal areas, however, these impacts should be kept to a minimum.

The reuse of drain water would also affect the Salton Sea by causing reduced inflows with higher salinities. The level of the sea could be lowered, or the rate of increase in elevation would be slowed. The salt loading would remain high, and the salinity would increase at a higher rate as a result of the reduced flow.

9.13 RETENTION BASINS

Retention basins are dams, dikes, or levees constructed uphill of structures to be protected, plus the basin areas formed thereby. At present, the East Highline Canal and the Westside Main Canal are subject to heavy damage from flash floods. Flood flows from the East and West Mesas carry heavy sediment loads. The flood flows scour canal banks and deposit sediment in canals, causing extensive, costly structural damage as well as interrupting water deliveries.

9.13.1 DESCRIPTION

Numerous instances of cost-effective retention basins exist. All sections of the MWD's Colorado Aqueduct subject to flood damage are protected by dikes.

Generally, water that collects in retention basins behind the dikes crosses the aqueduct in overshoot structures, or, alternately, the aqueduct passes in an inverted siphon under the channelized floodway. Similar dikes and floodways are in place on applicable sections of Interstate 8 and the Southern Pacific Railroad.

9.13.2 BENEFITS AND COSTS

Dikes and retention basins were installed several years ago to protect future canal sections of the Central Arizona Project. Runoff from summer flash floods in central Arizona that collects in the retention basins near the Gila River Indian Reservation is extensive enough for the Indians to have appropriated the water and diverted it to the reservation. In view of the extreme aridity of the Imperial Valley, it appears improbable that any useful quantity of water would collect behind retention basins built to protect the endangered canals in the District. However, such retention basins might well prove cost-effective solely as a means of damage prevention, including conservation of water that would have been lost because of foreseeable flood damage. Outlet works would need to be analyzed on a case-by-case basis for each retention basin. This analysis is recommended for the implementation planning phase scheduled for later.

9.13.3 ENVIRONMENTAL CONSIDERATIONS

The Westside Main and East Highline Canals are subject to heavy damage from flash floods carrying heavy sediment loads. Mammoth Wash traverses the Coachella and East Highline Canals at about the latitude of Calipatria. Approximately 15,000 acres drain into Mammoth Wash with an elevation drop of about 2,000 ft. The alternate canal built during the lining of East Highline Canal would be used for retention of flash floods and protection of the East Highline from the heavy sediments accompanying the flash floods. Potential environmental considerations involved in the excavation of this alternate canal are discussed in subsection 9.1.3.

Although the main purpose is to protect IID structures from heavy sediment, sporadic flows of water from flash floods would be routed to the Salton Sea in two possible routes. One would be via the Alamo River. This route traverses mainly agricultural land. The other route would take excess flow from the retention basin of the northern portion of the East Highline Canal directly to the Salton Sea via existing drains running to the sea north of the Wister Unit of the Imperial Wildlife Area. The Wister Unit is cultivated and extensively managed for waterfowl and serves as an important area for preserving California's waterfowl and other wildlife resources.

The Yuha Wash is in the southwest corner of the IID and empties into the Westside Main Canal south of Dixieland. Again, the alternate canal built during lining efforts would be connected into a retention basin. The sporadic flow would be diverted through existing drains to the New River and ultimately on to the Salton Sea.

Diversion of flash flood water to the Salton Sea would result in increased water level and possibly reduced salinity in the sea resulting from dilution. If salinity of the storm runoff increased because of evaporation in the retention basins, then the salinity of the Salton Sea would increase at greater than the current rate.

Additional environmental considerations would be the impacts from the construction necessary to prepare the alternate canals as retention basins, as well as the preparation of drains for the transport of the flow. These impacts may include air quality, noise, and cultural resources.

9.14 SYSTEM AUTOMATION AND CONTROL

The degree of automation and control of an irrigation delivery system has a direct effect on the flexibility of water deliveries to the farmers. The flexibility of frequency, rate, and duration of water applications is important to farmers because crop yields and economic returns are dependent on excellent water control. Irrigation systems are generally designed for delivery of water to farms to improve crop yields; therefore, the needs of the farmer should be considered in the design and operation of the delivery system. The IID has recognized the importance of meeting the farmers' needs and has continued to upgrade the canal control system through the addition of automatic and automated control structures and reservoirs. These facilities have enabled the IID to operate major sections of the canals as level pools, thereby providing an improved degree of control of water deliveries to the laterals.

Flexible canal delivery methods are relatively new in both concept and implementation. Most research on canal control has addressed conventional upstream control as is currently practiced by IID. A newer concept is downstream control, which can potentially provide improved service to farmers. The primary benefits of improving service to farmers include:

(1) Higher production/quantity of water applied
(2) Higher production/acre
(3) Better fertilizer efficiency
(4) Less fertilizer leaching
(5) Reduced waterlogging of soils
(6) Less drainage requirements
(7) Less tailwater

9.14.1 DESCRIPTION

As mentioned earlier, there are two primary methods of controlling an irrigation system: upstream and downstream. Conventional upstream control means releasing water from an upstream source in anticipation of demand downstream. Downstream control refers to the regulation of control structures based on downstream water levels. The essential factor is that downstream demand dictates water released into the system. At present, IID's system is operated through upstream control.

A. Upstream Control

Most canal delivery systems are operated using upstream control. With these systems, the primary function of the zanjeros and the hydrographers is to shuttle water around and maintain a relatively constant water level at the turnouts. There is little flexibility with this type of system because there is no way to shut the water off once it has entered the system. It is also difficult for the zanjero to adjust gates properly if there are many flow changes. Upstream control is very effective in water spreading because water can be distributed throughout the system on a strict timetable or rotation schedule. These schedules are designed for canal management rather than to meet farmers' needs.

An automated system can imply many concepts but generally refers to some type of automatic gate control to maintain a constant water level upstream of the gates. A constant level can be maintained immediately upstream, regardless of the flow rate; however, the water level immediately downstream may vary considerably. This type of automated control is that practiced on the All-American Canal and portions of the Westside Main, Central Main, and East Highline Canals. These automatic gates make the job of the hydrographer easier; however, the extra flow that is passed by may ultimately be spilled at the lower end of the canal system. There are a number of ways of automating upstream control of a canal system. Four methods are currently in use elsewhere:

(1) Neyrpic AMIL Gates - upstream automation on sloping canals

(2) Littleman Controller - upstream automation with float-controlled electric motors on gates

(3) Dynamic regulation

(4) Upstream control on the California Aqueduct

The Neyrpic Company of Grenoble, France, has had considerable success with their float-operated gates. The Neyrpic AMIL gates are mechanically simple with few moving parts and require no external power supply. Check structures using this type of gate frequently use multiple gates with only one automated. This is essentially the same operation as used by the IID on their automated check structures.

The Littleman controller is an electronic device developed by USBR personnel working on the Friant-Kern Canal. The sensor on this device consists of a float, taps, pulley and counter-weight assembly. Microswitches are tripped, which in turn activate timers that control the raising and lowering the gate motor controller.

Dynamic regulation is based on statistical estimation of anticipated demands. Water is released into the canal network based on these estimates, and water levels are monitored remotely to verify whether the estimates were correct. A computer program provides information for necessary adjustments in the supply. Although the approach has been successful, detailed hydraulic data is required for each canal and control structure for development of the computer hydraulic model.

The California Aqueduct facilities are controlled through five regional control centers with a Project Operations Control Center in Sacramento to direct and coordinate all operations. It also serves as a remote control backup. All gates, pumps, etc., are remotely controlled to maintain a series of level pools. Two computer programs are used in the control of the system. The first calculates anticipated flow rates for each section of canal, and the second calculates and readjusts gate openings. The operation of the gates within the system is not a strict upstream control basis but uses refined simultaneous gate openings to reduce hydraulic transients. This method minimizes the effect of distance from water source to diversion point.

B. Downstream Control

Downstream control, the control of releases based on downstream water levels, is often referred to as "demand delivery." This type of delivery is desirable from an agronomic viewpoint, and it simplifies canal operation because delivery schedules are not required. A downstream controlled system automatically responds to the opening and closing of farm turnouts. A city water system with a pressure pipe network is an example of a demand delivery system. A problem with applying this approach to a canal system is that shutting a turnout on a sloping canal will generally result in overtopping the canal banks. The use of a level top canal network minimizes this problem. Level top canals consist of a series of level pools connected by control structures that respond to downstream water surface elevations. Level top canals have the disadvantage that the banks on the lower ends must be higher than for sloping canals. This restricts the feasibility of converting sloping canals to level top operation.

The USBR has developed and tested an electronic device (EL-FLO) that controls the gate operation at the upstream end of a sloping canal, based on sensing the water level at the downstream end. The EL-FLO device has three control parameters that are difficult to determine and require a complicated computer program to analyze the hydraulics of the complete canal system. The EL-FLO method has been experimented with for over 10 years without being perfected.

Research has been under way in recent years by Professor Charles Burt of California Polytechnic State University, San Luis Obispo, California, to develop the logic for a new method of downstream control of sloping canals that will require very little hydraulic modeling of the canal system. The logic uses multiple-level measurements along each canal reach to provide a constant update of conditions in the reach. A microcomputer uses these readings to predict the consequences of gate movements and provides quick responses that minimize significant changes in water surface elevations. This ensures constant discharge at the farm deliveries. Two significant advantages of this control logic are that flow rates do not need to be measured in the main canals and that each pool can be operated by a separate but identical control program.

C. Recommended System

It is desirable to have the ability to deliver water to the farm deliveries on a demand schedule, but it is not necessary to have downstream control structures through the complete canal system to accomplish this. With the IID system, it will be much more economical to use the existing upstream control facilities on the canals and implement downstream control only on the laterals and the tail reaches of the canals. Implementation of this type of a control system will require regulating reservoirs below many upstream control structures. Downstream control structures will be required at the last control structure of each canal, at each lateral headgate, and at intermediate control structures along the laterals. Each of the control structures will require electric-operated automatic gates with remote supervision control from headquarters. The remote supervision control system will have three primary components:

(1) Telemetering equipment at the headquarters office to accept commands from an operator and to provide remote readout of flow data and counterpart equipment at each control structure.

(2) Communication systems such as land lines, microwaves, or very high frequency radio. It is proposed that this portion of the control system be integrated with that of the Power Division.

(3) Electrically operated machinery and microcomputer control systems in the field at each control structure to perform the desired functions.

The control panel at headquarters will include a graphic panel display of the canal system and will be capable of displaying data for each control structure on a CRT terminal. The readouts that will be available include:

(1) Water level above and below control structures
(2) Gate positions
(3) Flow rate and total flow
(4) Reservoir status
(5) Electrical power failure alarm
(6) High-low water level alarm
(7) Communications failure alarm

It is recommended that the control system be built in stages, commencing with the revision of the existing control structures to enable the remote readouts of water levels and flow rates and the complete supervision control of these structures. The ensuing steps in implementation should be:

(1) Install supervision control systems on regulatory reservoirs.

(2) Install remote-controlled automatic gates on laterals initially with upstream control.

(3) Install remaining regulatory reservoirs with control systems.

(4) Install downstream control on selected laterals, and conduct pilot test program.

(5) Complete installation of downstream control systems.

(6) After the complete control system has been installed and an operational history has been developed, develop a computer model to simulate the demand patterns. The model can assist the District in controlling the distribution system and in making more precise requests for releases from Hoover Dam.

This method of conservation will complement and greatly enhance the success of both the reservoir alternative (section 9.5) and the improved flow-monitoring alternative (section 9.7). It is therefore assumed that these three alternatives will be installed in an integrated program.

The specific assumptions used to estimate cost for this system would be:

(1) That monitoring includes the settings made at every farmer's delivery, settings at each of the 135 lateral reservoirs, six major reservoirs (approximate), 1,500 flow monitoring structures, and the settings at the head of each lateral, in addition to the automated facilities currently in operation.

(2) In addition to monitoring the above, control devices will be installed at all laterals and at all reservoirs. Both the monitoring and control activation is expected to be by radio communication.

(3) All of the foregoing equipment would be linked to a central computer at IID headquarters, which would receive the field input data by radio automatically while at the same time IID personnel are setting the demand matrix of orders into the computer to be integrated with the field data. The computer will constantly calculate hydraulic flow data and automatically adjust the settings of mains, laterals, and reservoirs to adjust to the fluctuations.

(4) The hydrographers would monitor system operations to ensure that there are no malfunctions and to serve as a backup for gate adjustments during such events. The zanjeros would open, close, or adjust the farmers' headgates as directed by radio from the IID headquarters personnel who are monitoring computer output instructions.

This system should be able to offer much greater responsiveness and accuracy in fulfilling customer orders. In so doing, it is expected that the estimated reductions in tailwater of 10% and operational discharge of 20% are reasonable. The combination of reservoirs, improved flow monitoring, and system automation is expected to reduce these losses as a unit.

9.14.2 BENEFITS AND COSTS

The benefit of this system is the estimated water conserved of 45,000 AF/year. However, it is probable that some parts of the IID system will not be adaptable to system automation. It is assumed for this analysis that only 60% of the IID system will benefit from automation, and both benefits and costs have been reduced accordingly in the following analysis. The estimated water conserved is thus 27,000 AF/year (45,000 x 0.6) and the associated benefits are:

$$\begin{aligned} B &= 27{,}000 \text{ AF/year} \times \$100\text{/AF} \\ &= \$2{,}700{,}000\text{/year} \end{aligned}$$

$$\begin{aligned} PW &= \$2{,}700{,}000 \text{ (BPWF)} \\ &= \$24{,}828{,}000 \end{aligned}$$

The cost of the project is estimated as follows:

Capital cost = $25,000,000 x 0.65[a] = $16,250,000 (includes monitoring equipment, control actuators, computer hardware, and communications system)

In addition, an annual O&M cost of $1,000,000 x 0.65 is estimated. The present worth of the O&M cost is:

PW = $650,000 (CPWF)
= $7,648,000

Total cost is:

Capital cost =	$16,250,000
O&M cost =	7,648,000
Total	$23,898,000

The benefit/cost ratio for this system is:

$$B/C = \frac{\$24,828,000}{23,898,000}$$

= 1.04 ($96/AF conserved)

This benefit/cost ratio is acceptable for the immediate implementation with the other elements of the Hydraulic Control Complex.

9.14.3 ENVIRONMENTAL CONSIDERATIONS

The primary physical impacts associated with system automation would be minimal. Very little physical disturbance would occur. The only construction activities would be those required to replace gates and install a control center. The construction of a control center is expected to occur within an existing IID facility. Secondary impacts of system automation are those associated with reduced flows through the drainage system and, ultimately, into the Salton Sea. The consequences of this reduced flow, as discussed previously, are increases in the rate of salinity rise in the Salton Sea and potential detrimental effects on the fish and wildlife dependent on the sea.

[a]The costs of the system have been reduced to a lesser degree than the benefits because many components of the system are required whether or not the entire IID is served.

CHAPTER 10

NONSTRUCTURAL WATER CONSERVATION METHODS: DISTRICT CONTROLLED

The structural methods of conserving water enumerated in Chapter 9 can be enhanced significantly with appropriate nonstructural supportive measures. This chapter presents the principal examples and evaluates their potential for water conservation.

10.1 MODIFIED DEMAND DELIVERY

Under the current IID irrigation water delivery procedures, a farmer normally orders water 1 day in advance of his requirement. In some cases, his order may be delayed 1 or 2 days if there is insufficient lateral capacity, but next-day service is usually available. The farmer's order will be for a specific flow rate in increments of 0.5 ft^3/sec to be delivered for a precise 24-hour period. This section presents a modification of the baseline method.

10.1.1 DESCRIPTION

The modified demand delivery method (now being tested in an IID pilot program) would be similar to the baseline method, except that a farmer would be given the option of either lengthening or shortening his irrigation run by as much as 4 hours in either direction. This program would be administered very simply by having the farmer inform the appropriate zanjero before he starts his morning run that a change in the order is desired. The zanjero would then act on the request as rapidly as feasible.

10.1.2 TECHNICAL EVALUATION

Under present conditions, a 24-hour run begins at about 7 a.m. for a farm located at the top of a lateral and at about 11 a.m. for a farm located near the end of a lateral. This means that a farmer at the top of a run has little flexibility for shortening his order but could lengthen it by the full 4 hours. However, the last farmer on a lateral would have the full 4-hour option in either direction. It would be expected that front-end farmers would calculate their orders on the short side, then lengthen the run, if necessary because of (1) the limitation on shortening a run for farmers at the top of a lateral, and (2) the relatively reliable flow at locations near main canals. The greater flexibility farther down a lateral would enable farmers to deal effectively with both under- and oversupply conditions.

The effect of this modified method of operations should be a reduction in tailwater. This measure is projected to produce a reduction in tailwater of about 60,000 AF/year (20% to 25% of 270,000 AF/year, see section 7.6). This estimate is preliminary and may be adjusted as more data becomes available from the IID's pilot program. The reduction in tailwater is expected as a result of more flexibility in meeting the farmer's needs, which engender a lower contingency in their orders while allowing timely correction of over and under orders when they do occur.

The cost of the new policy will be measured in the increased staff necessary to effectively administer the procedure. Discussions with IID personnel have resulted in an estimated increase of 70 zanjeros and associated management personnel. Table 10-1 gives the estimated annual cost of this program:

Table 10-1 - Additional IID Staffing Requirements for the Modified Demand Delivery Concept

Position	Number	Total Annual Cost[a] (1985 dollars)
Assistant superintendents	7	$ 455,420
Hydrographers	20	940,120
Zanjeros and patrolmen	70	3,290,420
Total	97	$4,685,660

[a]These costs were estimated using annual salary, plus employee benefits (35% of base), plus overhead for vehicles, administrative personnel, equipment, etc.
Source: Parsons, 1985.

Because no capital cost is involved in this measure, it can be compared directly to the annual benefit that occurs as a result of conserving water, in this case a total of 60,000 AF/year:

Benefit	Unit Value (1985 dollars)	Total Annual Benefit (1985 dollars)
60,000 AF/year	100/AF	$6,000,000

The benefit/cost for this measure is estimated at:

B/C = $6,000,000/$4,685,660
= 1.28 ($78/AF conserved)

The ratio above is definitely acceptable, and this option will be incorporated in the category "miscellaneous projects" listed in Chapter 12. This conservation measure is classified under "miscellaneous" for two reasons:

(1) The test program results are not yet final.

(2) It is probable that there will be a significant overlap functionally between this option and the "hydraulic control complex" discussed in Chapter 9. If so, many of the benefits and costs will be absorbed by the structural option, which is less labor intensive.

10.2 SEQUENTIAL WATER DELIVERIES

The sequential water delivery concept is a variation of the demand delivery concept that is now being used in Arizona with some success.

10.2.1 DESCRIPTION

The sequential procedure is designed so that a farmer may order not only a specific flow rate, but he may also name a specific time interval, e.g., 10 ft^3/sec for 16 hours. On receiving a day's orders, the Water Master will integrate them to develop the overall flow plan and will inform the growers when their orders will start.

10.2.2 TECHNICAL EVALUATION

By allowing a farmer to specify both rate and run duration, the farmer can tailor his order to his own unique on-farm system. This will clearly allow better management of deliveries. However, a reasonable expectation of success under the District's baseline procedure is for a farmer to estimate his needs within ±10%. In many cases, the farmer is not that close, and he normally orders on the high side to ensure that he has enough water. The net result is tailwater that is estimated at over 14% of on-farm consumptive use (240,000 AF/1,700,000 AF, see Chapters 4, 5, and 7). Therefore, by providing a more effective water management tool to the farmer, he will probably use less water because of better estimates and more effective use of the resource. But the farmer's estimates will still be imperfect and, unless he is given the option of extending his run very close to the end, he will still tend to order more than he needs. Therefore, it is assumed that this aspect of the modified demand alternative (section 10.1) will be incorporated in the sequential delivery alternative as well. The sequential delivery measure is thus expected to be slightly more effective than the less complex modified demand method. It is estimated that tailwater will be reduced by 30% using this alternative with no change in operational discharge, for a total of about 80,000 AF/year of water conserved.

The cost of this measure would also be determined by the increased staff necessary to execute it. Based on results observed in Arizona and on an analysis of the IID's operations, it is expected that the zanjero staff would need approximately 200% augmentation, primarily to cover night-shift activities that would be needed to accommodate the variable duration scheduling. Table 10-2 gives the additional staffing costs. As in the previous case (section 10.1), the annual costs can be compared to the annual benefits.

Table 10-2 - Additional IID Staffing Requirements for the Sequential Delivery Concept

Position	Number	Total Annual Cost (1985 dollars)
Assistant superintendents	12	$ 780,720
Hydrographers	36	1,692,216
Zanjeros and patrolmen	176	8,273,056
Total	224	$10,745,992

Source: Parsons, 1985.

The 15% of tailwater estimated to be conserved yields 36,000 AF/year which, when valued at $100/AF, indicates a total annual benefit of $3,600,000. The benefit/cost ratio is thus:

$$B/C = \$8,000,000/\$10,745,992 = 0.74$$

This benefit/cost ratio is not competitive with that of the modified demand method and, therefore, not economically justified. To support the validity of this conclusion, a sensitivity analysis was conducted assuming approximately a 35% tailwater reduction and a staff augmentation of only 175% rather than 200%. The results were:

$$B/C = \$9,400,000/\$9,402,743 = 1.0$$

This result is also not as cost effective as the modified demand concept. For these reasons, the sequential delivery concept will not be considered further in this report. However, because the second benefit/cost ratio is borderline, a small-scale trial of this measure is justified to probe the minimum staff augmentation required to support the measure.

10.3 STANDARD DELIVERY HEAD INCREMENTS

A third concept for water conservation through delivery management would involve the standardization of delivery head increments described below.

10.3.1 DESCRIPTION

The current IID practice is to allow farmers to order water in delivery head increments of 0.5 ft^3/sec. The concept in this section is to increase the size of the increment to about 3 ft^3/sec and to require consumers to order in multiples of this standard delivery head, i.e., 3 ft^3/sec, 6 ft^3/sec, 9 ft^3/sec, etc. This concept can only be applied in conjunction with a sequential procedure (as described in section 10.2) because most farmers would probably not be able to match their needs with the volumes available. Thus, the farmers would be allowed to specify both the number of standard increments and the run duration.

10.3.2 TECHNICAL EVALUATION

This alternative is hypothesized to conserve water by allowing the District to more easily shut off a run early if requested because it would be easier to find another user with the same demand rate, if such rates were standardized. This basic concept is valid; however, many farm systems in the IID would simply not be able to fully adapt to this concept, and extensive resistance would be expected from even those who could adapt because of the expense and effort involved.

For this reason, the concept is considered infeasible. Moreover, since it would be used in conjunction with the sequential delivery system, economics rule out this method (as demonstrated in section 10.2). Therefore, this measure will not be considered further.

10.4 TAILWATER ASSESSMENTS

10.4.1 DESCRIPTION

The IID has been using a tailwater assessment procedure for many years as part of its 13-Point Program (Appendix F). The procedure consists of (1) monitoring tailwater discharge, and (2) assessing a triple charge for the water order if tailwater exceeds 15% of the order. This concept is analyzed below.

10.4.2 TECHNICAL EVALUATION

The IID program of tailwater assessments has been successful in reducing tailwater. The current District estimate is 20,000 AF/year (see Chapter 4); however, experience with the program indicates that its effectiveness has been limited for the following reasons:

(1) The frequency of monitoring tailwater has been less than optimum.

(2) The farmers have been allowed to change their delivery points to other fields in mid-run.

(3) For growers of high-cost crops, the assessments have been so small compared to other production costs that the user is willing to accept a penalty more or less as insurance for the crop.

Nevertheless, when used in conjunction with other water conservation programs such as the structural systems discussed in Chapter 9, the tailwater assessments will continue to act as a deterrent to the wasteful use of water. However, this should not become the cornerstone of a major water conservation effort because the system depends on the "consent of the governed," and voluntary compliance is the goal rather than a system of punitive measures. For this reason, the use of penalties should be rare and positive measures that reward conservation should prove more effective in the long run.

In summary, an expansion of the tailwater assessment system beyond its present scope would quickly reach a point of diminishing return; it is therefore recommended that no expansion take place. Nevertheless, the current program is generally having a positive effect and should be retained with its present scope, at least until other conservation measures make this measure unnecessary. However, the program's following shortcomings, recognized by the IID, should be corrected:

(1) The authorization for farmers to change their delivery points during a run should be rescinded.

(2) Monitoring frequency should be increased.

The cost effectiveness of the program is estimated as follows:

Benefit = 20,000 AF/year x $100/AF

= $2,000,000/year

Cost = expense for additional operational personnel (estimated to be 3 superintendents and 35 zanjeros and patrolmen)

= $1,800,000/year

B/C = $2,000,000/$1,800,000
= 1.11

These figures indicate that when other measures begin to reduce tailwater significantly the assessment program benefits may be reduced to a degree sufficient to make the program obsolete. The district must, therefore, continue to evaluate the effectiveness of assessments to accurately pinpoint when to end the tailwater assessments.

10.5 INVERTED RATE STRUCTURE

Akin to a tailwater assessment program is to simply increase the charge for each succeeding unit of water. This concept is also a variation of an incentive program.

10.5.1 DESCRIPTION

The concept of an inverted rate structure is well known as a conservation measure. In fact, a variation of it is currently in use now in some major cities. This measure consists of a rate structure such as:

Increment (AF/acre)	Rate ($/AF)
1st	$ 5
2nd	7
3rd	9
4th	11
5th	13
All after	20

To execute this plan, it would be necessary to know the acreage served by each farm delivery and to bill accordingly. The billing would probably need to be on an annual basis and would escalate as the end of the year approached.

10.5.2 TECHNICAL EVALUATION

The success of this measure depends on:

(1) The severity of the rate increase per unit volume.
(2) The degree to which the rates are accepted as equitable.

It is probable that the appropriate rate structure will cause a reduction in water use in a very cost-effective manner. Therefore, is recommended that the structure shown in subsection 10.5.1 be evaluated and modified as appropriate by the District's staff and then initiated for a trial period. During this test period, which should last 1 year, the reaction to it and its success in water conservation should be monitored carefully. At the end of the trial, an assessment should be made to continue, to stop, or to modify the program.

10.6 INCENTIVE PROGRAMS

There are many ways that farmers can be given a monetary incentive to conserve water. This section presents one concept for review as a further step in developing a practical way of rewarding those farmers who practice water conservation. This incentive method should be appraised extensively and then given a field trail prior to initiating a Districtwide application.

10.6.1 DESCRIPTION

The possible incentive program considered in this section is based on an allocation of water to farmers at rates dependent on the specific crop grown. For example, suppose a farmer informs the IID that he plans to grow alfalfa on his farm. The IID would allocate water to this user at a hypothetical rate of 7 AF/acre/year. Instead, if the farmer plans to grown barley, the rate could be 4 AF/acre/year. The rates used for each specific crop must be analyzed carefully, but clearly a reasonable crop-specific water allocation table could be created. After these rates are established, should a farmer use less than his allotment he would be given a cash rebate or credit against his water bill. The amount of the incentive is a subject for extensive debate; however, for the purpose of discussion, a rate of $20/AF conserved is assumed. Thus, if an alfalfa grower with 160 acres in production uses only 6 AF/acre/year instead of the 7 AF/acre allowed, he would receive a rebate of:

Rebate = (7 minus 6) AF/acre x 160 acres x \$20/AF/year
= \$3,200/year

This program could be combined with an inverted rate structure as well, by charging a higher rate for water use beyond the allotted amount. This is an optional scheme that may provide a sound reinforcement to the incentive concept.

10.6.2 TECHNICAL EVALUATION

The amount of water conserved by an incentive program is largely dependent on the magnitude of the incentive. The objective of an IID incentive would be to encourage less water use primarily by increasing efficiency. The level of incentive necessary to do this will be much better defined after field trials, and a final assessment must wait until that time. However, it is highly probable that an economically feasible variation of an incentive program can be defined. On the basis of recommendations of the IID staff and its consultants, if the IID Board of Directors plans to implement the program, they should approve:

(1) Base allotments for each crop.
(2) Rate at which the incentives will be awarded.
(3) Duration of the program.

This action would represent the first step in the evolution of a feasible program. The ensuing years would provide the input data that would allow a reasonable adjustment of the program as conditions and attitudes change within the District. The administrative details for the program dealing with questions of differing soils, crops changes, tenant farmers, etc., must be resolved; however, there are no insurmountable obstacles to the program envisioned.

10.7 TRAINING PROGRAMS

To foster a water conservation program, both the responsible agency and the public must known the reasons "why" and "how" it is to be done.

10.7.1 DESCRIPTION

The IID is currently working to conserve water by advising the District's constituents how to do so. These ongoing programs are:

(1) Tailwater Recovery Demonstration Program
(2) Water Conservation Document Distribution
(3) Field Irrigation Demonstration Program
(4) Irrigator Training Program
(5) District Personnel Training

In addition to this array of programs, a few of the many other potentially valuable training programs could include:

(1) Optimum leaching techniques
(2) Low-water-use crop production
(3) Farm economics and business practice

10.7.2 TECHNICAL EVALUATION

These programs will help the conservation effort. However, the benefits that result are impossible to define economically, and no attempt will be made to do so. The cost for these programs should be identified and tracked as an overhead item to be prorated to the other water conservation efforts being implemented.

10.8 ENVIRONMENTAL CONSIDERATIONS

The nonstructural conservation methods discussed in this chapter all create less operational wastes. These nonstructural methods imply that there is no physical improvement to the system (with the exception of system automation). However, several of these nonstructural methods may not be practical without the concurrent implementation of structural improvements in the system. Environmental considerations should include the cumulative impacts of implementing these conservation measures.

The first three nonstructural methods (sections 10.1 through 10.3) would result in more efficient regulation of deliveries to the farmers' headgates. As a result, less water would be spilled into the drainage system through operational spills. The environmental effects that should be considered include reduced flows through the New and Alamo Rivers and reduced flows into the Salton Sea. The change in salinity of the sea is also a consideration.

The remaining nonstructural conservation methods (sections 10.4 through 10.7) effectively reduce the quantity of water delivered to a farmer. As a result, less water should be wasted as tailwater. Consequently, less tailwater will enter the drains and the water in the drains will thus be more saline than without conservation. Therefore, the water flowing into the New and Alamo Rivers and the Salton Sea will be reduced and the salinity will be higher. The level of the sea will be affected, and the rate of salinity increase will be greater.

CHAPTER 11

ON-FARM WATER CONSERVATION METHODS

In Chapters 9 and 10, the actions that the IID can take to conserve water, either before or after delivery to the consumer, have been the focal point of analysis. In Chapter 11, the spotlight moves to the actions that the farmer can take to conserve water, with or without IID's help.

11.1 LAND LEVELING

Efficient irrigation often requires extensive land preparation prior to actual start of farming operations, e.g., installing drainage tile, disking, and land leveling - the topic of this section.

11.1.1 DESCRIPTION

Land leveling is the procedure of grading the land surface to improve water distribution and to control irrigation and surface drainage. The main objective of leveling the land is to create a surface for the even distribution of water to each plant in the field during irrigation. Normally, the term "land leveling" means grading to attain controlled drainage, using slopes engineered to cause flow parallel to furrows or borders and, simultaneously, to a drain on one side of the field at the lower end. Less often, the term can also apply to "dead level" grading where slopes very close to zero are used. As practiced in the Imperial Valley, land leveling can be categorized into two methods.

(1) The first method involves smoothing out the upper portion of the soil stratum by means of a float, drag, scraper, or land plane. In this method, small quantities of earth are moved relatively short distances on the farm field to create the desired land level. This type of land grading is not meant to change the natural slope of the land but merely to create a better farming surface for machinery and irrigation/drainage operations. Drag scrapers are also used for smoothing by some farmers. The individual farmer can do much to change the slope of the land gradually over a period of several years by observing the low areas where water ponds during irrigation periods and the high spots that receive insufficient water during irrigation. After crop harvest, the low areas can be filled level with the surrounding land by using soil borrowed from the high spots.

(2) In the second method of land leveling, which is more frequently applied, substantial quantities of earth are redistributed by large earthmoving machines. A new uniform slope and an even surface are established by transporting earth from areas with higher elevations to lower areas along calculated gradelines within specific field boundaries. Land leveling of this type normally involves land surveying and the use of large earthmoving equipment on large farms.

Land leveling at this scale is conducted with the use of private contractors trained and experienced in this type of work; it is rarely undertaken by the landowner.

Aside from conventional equipment used for leveling, land-laser equipment is used extensively on Imperial Valley farmland to aid in the land-leveling operations. Laser land leveling involves the use of laser beams during grading operations. Many farmers own and operate laser equipment to maintain the precision of leveling necessary for the even distribution and control of water on their fields in between cropping periods.

Land leveling is critical in many irrigation practices such as level basin irrigation, sometimes referred to as dead-level irrigation. Often these irrigation practices involve a significant degree of land leveling for even water distribution. The main purpose of land leveling is the even distribution of irrigation water on the fields. Proper land-leveling techniques will increase the efficient application of irrigation water by creating a smooth uniform surface for even water distribution to the tail end of farm fields. Leveling techniques that reduce the natural slope of the land may increase the potential for water penetration into the soil by reducing the velocity of the water over the field.

11.1.2 BENEFITS AND COSTS

The benefits of land leveling are:

(1) Potential improvement in crop.
(2) Probable reduction in tailwater.

The second item is the only economic benefit that will be quantified in this study; however, the principal justification to farmers for land leveling is improved yield. The estimate of economic benefit from land leveling is made by simply assuming that this procedure:

(1) Gives an irrigator more reaction time to make adjustments to the irrigation pattern because the water is moving more slowly across a field.

(2) Enables a grower to decrease his order slightly because of better penetration.

The quantity of water potentially conservable in this way is on the order of 35% to 40% of current tailwater, or approximately 100,000 AF/year.

Therefore, the benefits of land leveling are:

B = 100,000 AF/year x $100/AF
= $10,000,000 AF/year

The present worth of these benefits is thus:

PW = (BPWF) ($10,000,000/year)
= $91,955,000

The costs for the measure occur because it is estimated that over 90% of Imperial Valley farms have not been land leveled to optimize water use. Many farms have been "smoothed;" however, few have been actually leveled to achieve optimum water use and minimum tailwater. The cost of "optimization" leveling for 450,000 acres at $150/acre is:

Capital cost of land leveling = 450,000 acres x $150/acre
= $67,500,000

In addition to the initial leveling, the maintenance and releveling will require about $15/acre annually, at a cost of:

O&M cost = 450,000 acres x $15/acre
= $6,750,000

The present worth of the annual O&M cost is:

PW = (CPWF) ($6,750,000)
= $79,426,000

Total cost is:

Capital cost =	$ 67,500,000
Present worth annual O&M cost =	79,426,000
Total cost	$146,926,000

Because the principal reason for the land leveling is to improve crop production, it is reasonable to expect the farmer to share costs for this measure. Therefore, the proposal considered in this report is for the IID and growers to each pay 50% of the cost of the program: the IID's benefit would be conserved water and the farmer's benefit would be a better yield. The program would be completely voluntary on the part of the farmer with the only stipulation being that the IID must approve the grading plan and final product to ensure that the optimum final grades (agreed-to in advance) are achieved. Based on this scenario, the benefit/cost ratio for the leveling concept is:

$$B/C = \frac{\$91,955,000}{\$74,963,000}$$

= 1.23 ($82/AF conserved)

This ratio is completely acceptable for further consideration.

11.2 TAILWATER PUMPBACK SYSTEMS

The tailwater recovery system discussed in Chapter 9 dealt with a Districtwide program that recovered tailwater after being released from a farm. That process required expensive treatment prior to reuse because of possible contamination with pesticides, weeds, and biological pests. The on-farm tailwater recovery system does not require treatment because the water would contain no contaminant not picked up on the farm itself and, therefore, would be introducing no new problems, although scalding, weed control, and salinity must be considered in system design to minimize the negative effects.

11.2.1 DESCRIPTION

The tailwater pumpback system is used to reduce the loss of on-farm water created by surface runoff during irrigation. Tailwater pumpback systems are basically designed to collect irrigation water that flows off the low end of a field following periods of irrigation, to store it briefly for future use, and to return the water for reapplication to the same or adjacent field. The three primary objectives for installing tailwater pumpback systems in the Imperial Valley are to:

(1) Increase irrigation efficiency
(2) Reduce drainage problems
(3) Conserve water

Various benefits can be derived by installing tailwater pumpback systems. A substantial amount of both dissolved fertilizers and pesticides can be recovered in the tailwater and then returned to the field to be reused, which may result in significant cost savings. The application and removal of water from the field can be accomplished more rapidly, and the ponding of water at the low end of the field is, therefore, under tighter control. Tailwater systems can also act to reduce permanent loss of soil on the farm and reduce sediment buildup in drainage structures. The absence of tailwater recovery systems along with inefficient irrigation practices can contribute to water loss in drainage ditches and crop damage due to the ponding of water.

The problems associated with the use of tailwater on fields, such as scalding of plants, transfer of weed seeds, and increased salinity of applied water, can be significantly reduced if not eliminated by a proper design of the tailwater pumpback system, coupled with specific farming practices. Any design of a tailwater distribution system should be directed at diluting the tailwater with delivery water prior to application to minimize the possibility of scalding and salt damage to crops. Transfer of weed seeds via pumpback systems can be minimized through proper maintenance of tailwater ditches for weed removal. More effective weed control in design of the pumpback systems may include:

(1) Changes in cultural and management practices such as regular summer leaching of the fields.

(2) Restriction of pumpback in hot months (e.g., August).

(3) Restriction of pumpback to nighttime.

Typical tailwater pumpback systems in the Imperial Valley consist of a collection ditch connected via an 18-in.-diameter culvert to a temporary storage pond designed to contain the tailwater flow, a sump and pump, and a

12-in.-diameter return pipeline to the farm head ditch. The capacity of the pond is important in the design of a system and is dependent on such factors as volume of applied water and tailwater, the field acreage served, and the irrigation method practiced. Collection sumps are typically 48-in.-diameter concrete vaults, approximately 7 ft in depth. Pumps may be installed in various locations in relation to the storage pond and return pipeline but are typically installed directly above the sump.

Tailwater pumpback systems have been installed in the Imperial Valley primarily for demonstration purposes. The application of tailwater pumpback systems for Imperial Valley farms should be evaluated on an individual basis because of the variation in field acreage and layout, crops grown, and irrigation methods practiced. For instance, those landowners farming fields with relatively no slope may not generate enough tailwater to justify a pumpback system.

The relatively simple prototype system used to establish the benefit/cost ratio for this measure consists of the following principal elements:

(1) A collection/storage pond with a capacity of 3 AF.
(2) A 15-hp, nonclog, diesel-powered turbine pump equipped with fuel tank.
(3) A 12-in.-diameter, 3,500-ft-long, low-pressure discharge pipe.

The operational scenario assumes a 160-acre field with a water order of 12 ft^3/sec for 48 hours, i.e., total volume of 48 AF. It is further assumed that 8 AF of tailwater will be collected and pumped back at a rate of 3 ft^3/sec. The pumping is assumed to begin approximately 12-15 hours after the irrigation run begins.

11.2.2 BENEFITS AND COSTS

The benefit obtainable from a comprehensive on-farm program of tailwater recovery is as high as 95% of the 270,000 AF/year attributed to tailwater loss; however, it is doubtful that total consumer cooperation will occur without an incentive program or without the IID bearing the brunt of the installation cost. It is, therefore, assumed that the IID will pay for the installation of the system and the O&M costs. It is estimated that the offer would attract 30% of the on-farm consumers and would, similar to land leveling, eliminate 35% to 40% of the tailwater, or approximately 100,000 AF/year. The assumption just stated may seem optimistic; however, it is probable that the farmers who are attracted to the program now waste much more than 30% of the tailwater or they would not be interested. The benefit is thus:

B = 100,000 AF/year x $100/AF
= $10,000,000/year

The present worth of this annual amount is:

PW = $10,000,000; 8.125%; 37 to 40 years
= $10,000,000 (BPWF)
= $91,955,000

The costs of the program to the District would be the capital cost of the installed system, plus the annual O&M:

Unit System Capital Cost

Excavation of pond	$ 8,000
Pump and tank	7,000
Pipeline	30,000
Total	$45,000

This cost is for one system that represents 160 acres out of approximately 450,000 acres in use in the District at any one time. Therefore, the total cost of the program covering 30% of the land is:

$$\text{Total capital cost} = \frac{135{,}000 \text{ acres}}{160 \text{ acres}} (\$45{,}000)$$
$$= \$37{,}969{,}000$$

The annual O&M cost for the system is estimated at $2,000/year/installation for a total of:

$$\text{Total annual O\&M cost} = \frac{135{,}000 \text{ acres}}{160 \text{ acres}} (\$2{,}000)$$
$$= \$1{,}688{,}000$$

The present worth of this annual cost is:

$$\text{PW} = (\text{CPWF})\ (\$1{,}688{,}000)$$
$$= \$19{,}862{,}000$$

The total program cost is thus:

Capital cost =	$37,969,000
O&M cost =	19,862,000
Total	$57,831,000

The benefit/cost ratio is thus:

$$\text{B/C} = \$91{,}955{,}000/\$57{,}831{,}000$$
$$= 1.59\ (\$63/\text{AF conserved})$$

This benefit/cost ratio is excellent. Clearly, the concept should be implemented for those farms with serious tailwater problems. To accomplish this, the District should establish an internal responsibility for the interview and investigation of farmers requesting the program. When reasonable surety exists that a profit can be made, the IID should proceed.

11.3 LOW-WATER-USE CROP SELECTION

A change in normal cropping patterns, unless dictated by agricultural economics, is extremely difficult to bring about for such purposes as water conservation. This fact is especially true in areas such as the IID service area where the water supplier has little or no control over crop selection by the farmers. Nonetheless, it must be recognized that some crops can thrive on less water than others. Also, some crops are more salt tolerant than others and can perform adequately with little water for irrigation, thus requiring a lesser depth of water for the leaching function. These facts were the basis of the following analysis.

11.3.1 DESCRIPTION

Considering the length of the growing season and the consumptive use of each crop presently cultivated in Imperial Valley, it is clear that alfalfa, the most widely grown crop, is also one of the most water-demanding (Table 11-1). Obviously, the choice of crops is not based on water requirement but on other, more economically relevant factors. With appropriate incentives (such as those described in section 10.6), it is conceivable that the growers' choice of crops can be influenced toward the less water-intensive ones and away from alfalfa. Clearly, these decisions have important socioeconomic implications and cannot be considered in a vacuum.

11.3.2 BENEFITS AND COSTS

The discussion of benefits and costs must remain qualitative at this point. The benefits will almost certainly be a reduction in on-farm consumptive use. The maximum amount of conservation would be on the order of 250,000 AF/year if mass conversion from alfalfa to garden crops took place; however, this is unlikely. Because of the uncertainty in any estimate of this parameter, no quantitative analysis of this alternative can be made until more data is obtained through field experiments.

The cost of this program would be minimal because the loss of direct District revenue would be more than matched by the value of conserved water. Therefore, this concept should be given serious consideration for a trial run.

A second variation on this same theme would be tied to educational programs demonstrating how it is possible to make more money by growing different crops. This type of program would have to be strongly supported with field data, preferably in a test by a local farmer. Here, the District would contract with a farmer to grow a specific crop with a guaranteed minimum return. If the farmer can get more on the market than the District will pay, he would be free to do so and the IID would owe nothing. The cost of this program would depend on the success of the crop, and if crops are selected carefully, the cost will be zero.

11.4 HEAD DITCH LINING

An on-farm lining program similar to the District's lateral lining program is discussed in this section.

Table 11-1 - Normalized Annual Water Demand of Crops Grown in Imperial Valley

Crop	Consumptive Use[a] (ft)	Cropping Factor	Normalized Annual Water Use
Garden Crops			
Broccoli	1.7	1	1.7
Carrots	1.3	1	1.7
Lettuce	1.4	2	2.8
Cantaloupe	2.3	2	4.6
Other melons	2.3	2	4.6
Watermelons	2.3	2	4.6
Onions	1.9	1	1.9
Squash	1.7	1	1.7
Tomatoes	2.3	2	4.6
Vegetables (misc)	1.7	2	3.4
Field Crops			
Alfalfa	5.4	1	5.4
Barley	1.8	1	1.8
Bermuda grass	3.6	1	3.6
Cotton	3.6	1	3.6
Rye grass	2.5	1	2.5
Sorghum	2.5	1	2.5
Sudan grass	2.5	1	2.5
Sugar beets	3.7	1	3.7
Wheat	2.1	1	2.1
Miscellaneous	2.5	1	2.5
Permanent Crops			
Asparagus	4.2	1	4.2
Citrus fruits	3.8	1	3.8
Duck ponds (feed)	3.0	1	3.0
Jojoba	3.8	1	3.8
Trees and vines	3.8	1	3.8
Miscellaneous	4.2	1	4.2

[a]Consumptive use values do not reflect water-use requirements for leaching. For unit values, see Table 7-6.

Source: Blaney and Criddle, 1962; UA, 1968; Kaddah and Rhodes, 1976; Donovan and Meek, 1983; DWR, 1983c; Parsons, 1985.

11.4.1 DESCRIPTION

Each landowner is responsible for construction and O&M of all of the water distribution system features beyond the District-operated headgates located at the edge of the District's ROW. A vital component of the on-farm water distribution system is the farm head ditch that functions to distribute irrigation water evenly to the head of the field. The landowner's head ditch begins immediately after the District-operated headgate, which represents the end of the District's ROW and the beginning of the landowner's turnout, except in certain cases where a farm road may separate the headgate from the head ditch. Each head ditch is located at the end of the field with the highest elevation, and the ditch typically runs perpendicular to its respective District supply lateral, generally spanning the entire length of a field.

Farm head ditches in the IID are typically open trapezoidal channels, often lined with a 1.5-in. layer of concrete. A typical existing concrete-lined head ditch is 2.5 ft in height with a 2-ft base and 1:1 side slopes. Unlined head ditches having a capacity comparable to lined ditches are notably larger, with side slopes being less steep. Water is distributed to the farm field from concrete-lined head ditches by the use of adjustable, metal slide-type gates, mounted on the side of the ditch. Concrete piping is often used to transport water through the side of the head ditch to the field. Slide-type gates can be adjusted easily to provide the desired flow rate of water to each tank or section of field irrigated.

Prior to 1984, approximately 80% of all of the landowners' head ditches in the IID had been concrete lined (IID Water Conservation Plan, 1985). The process of lining farm head ditches with a layer of concrete has been steadily implemented by Imperial Valley farmers for the past 30 years in which they have lined approximately 2,400 miles of head ditches (IID Water Report, 1984). The history of head ditch lining in the Imperial Valley can be divided into three time periods based on the ditch-lining rate for discussion purposes. Table 11-2 summarizes the lining rate for each time interval along with the cumulative percentage of lined ditches. The rate of lining head ditches over

Table 11-2 - Historical Head Ditch Lining (1954 to 1983)

Interval Date	Lining Rate (miles/year)	Duration (years)	Cumulative Lined Ditches (%)
1954-1964	111	10	43
1964-1977	69	13	73
1977-1983	33	6	80

Source: IID Water Report, 1984.

the past 20 years has decreased in relation to the increase in the miles of ditches lined. Difficulty arises when one attempts to project the rate at which farm head ditches will be concrete lined in the future because that rate is dependent on many interrelated variables. If head ditch lining were to continue at the 1983 rate of 33 miles/year, lining of all farm head ditches would be completed within the next two decades.

Most of the farm head ditches warranting concrete lining because of problems associated with water seepage and infiltration, excessive aquatic weed growth, or O&M have previously been lined. The remaining unlined earthen head ditches can be grouped into the following two categories:

(1) Ditches in need of lining and scheduled to be lined in the future as funds become available to the farmowner or as the economic advantages increase.

(2) Remaining unlined earthen ditches are either located in areas where the soils do not exhibit high seepage rates or do not experience significant aquatic weed growth to warrent routine ditch maintenance or operational implications. Often, ditches located in soils with excessive seepage rates experience little to no seepage due to buildup of fine-textured soil particles and clayey material on the sides and bottom of unlined ditches, creating a semi-impermeable membrane that restricts seepage through the soil until the ditch is dredged again.

Farmers have installed concrete-lined head ditches mainly to facilitate irrigation water distribution operations, thereby reducing O&M costs and, to a lesser degree, reducing damages caused by seepage. Lining ditches has basically been an economic decision by the farmowner. If substantial cost savings associated with the O&M of the head ditch can be justified, then concrete-lined ditches are installed. Thus, the number of ditches previously lined has been dependent on the quantity of savings through decreased labor anticipated by the farmowner.

Concrete-lined head ditches present certain advantages over unlined ditches. Lining ditches can significantly reduce O&M costs to the farmer and can reduce seepage to adjacent farmland. Also, lining ditches often increases the available land for crop production by reducing the farmland area required for maintenance of earth ditches.

There are many obvious O&M problems associated with an unlined earthen ditch. Unlined ditches have to be dredged and reformed periodically because of aquatic weed growth and soil erosion. Buildup of aquatic growth in the ditches often reduces the flow of water in the ditch and decreases the effective channel area, thus raising the height of the water in the ditch. Aquatic weed growth can also interfere with water distribution to the farm field as inlet pipes become clogged.

11.4.2 BENEFITS AND COSTS

The majority of water conserved through ditch lining would result from improved irrigation water distribution at the head of the farm field. Improved water delivery and distribution on the farm would result in a decrease in tailwater. Minor quantities of water conserved by lining ditches would stem from the virtual elimination of losses resulting from seepage through the wetted perimeter of a ditch and by the elimination of consumptive water use from the growth of aquatic vegetation in unlined ditches.

Since 1954, the IID has already lined approximately 2,400 miles of farmers' head ditches, and the program is continuing. However, there has been a trend to fewer miles each year, presumably as the farms most in need of such a system are provided with one. For this reason, the forecast for the future exploitation of the concept is not bright. Nevertheless, the program should be continued to the degree feasible; however, the alternative will not be relied on for much further conservation. The process must continue at least as a maintenance activity on previously lined ditches in need of refurbishing.

11.5 IRRIGATION SCHEDULING

On-farm operational efficiency is closely tied to getting the "right" amount of water to the field at the "right" time. This section discusses that important concept.

11.5.1 DESCRIPTION

Many factors determine irrigation frequency and how much water to apply at each given irrigation. A discussion of these factors is not included here because the matter is well documented in textbooks. Methods used to establish on-farm irrigation scheduling vary from the elementary (feeling the surface layer of soil) to the technologically sophisticated (computerized data banks connected to CIMIS[1] and coordinated with soil-moisture sensors installed at appropriate field locations). In between those extremes lies a range of methods for irrigation scheduling such as tensiometers, gypsum blocks, or neutron probes used as sensors in combination with assessment of ambient climatic conditions. The use of sophisticated irrigation scheduling techniques is most practical on very large farms (several thousand acres) or on a Districtwide basis if the District itself operates or directs the operation of individual farm irrigation systems. Computer software packages are available for medium-sized farms to input weather and soil-moisture data on an ongoing basis and to obtain the anticipated date and depth of the next irrigation on a daily basis; however, major changes in operating procedures would be required to shift from current practices to state-of-the-art irrigation scheduling. This is not to say that it is impossible or unadvisable to consider some changes that might make proper irrigation scheduling a reality.

The main advantages of using moisture-sensing devices and irrigation scheduling techniques are that they:

(1) Maintain a readily available moisture supply in the soil root zone.

[1]"California Irrigation Management Information System," a network of agroclimatic stations, remotely connected to a central computer at Davis, California, reporting continuous weather conditions for evapotranspiration calculations.

(2) Prevent excessive application of water because the guesswork is minimized.

Studies of farms using irrigation scheduling have generally shown significant water savings and yield improvement. The following actions could be used to achieve improved irrigation scheduling:

(1) Install moisture-sensing devices in strategic locations in irrigated field. Devices such as gypsum blocks, tensiometers, and neutron probes provide an estimate of the soil-moisture condition between irrigations. This information, coupled with climatic and crop stage data, can help establish the date and depth of the next irrigation.

(2) Provide educational materials to growers concerning the availability of continuous local climatic data from the CIMIS network, as well as its use in conjunction with soil-moisture data and crop stage.

(3) Establish a computerized irrigation scheduling software system for Imperial Valley, accessible by voice and/or terminal modems, for instantaneous computations of irrigation scheduling data. This system would then be widely publicized, and its use would be encouraged through demonstrations, television advertising, water-bill inserts, and IID field personnel (use of such a system would presuppose availability of water on demand, or at least on short notice).

11.5.2 BENEFITS AND COSTS

By itself, irrigation scheduling does not conserve water. It only permits the farmer to replenish the depleted moisture in soil at appropriate times with minimal stress to the crop being grown. However, the most important aspect of correct irrigation scheduling is in its ability to account for water. It is this accounting that holds the potential for water savings by taking the guesswork out of irrigation. The District is currently operating a pilot program of irrigation scheduling. The results to date have been mixed, and no further analysis will be conducted on this method until definitive results are available from the IID program.

11.6 LOW-WATER-DEMAND IRRIGATION METHODS

Methods of irrigation, as well as crop selection, determine the innate water demand of a farm. This section discusses conservation potential in changing current patterns.

11.6.1 DESCRIPTION

All irrigation systems are intended to supply the evapotranspiration requirement of the crops being raised, while keeping losses to a minimum. For the purposes of this section, irrigation methods are divided broadly into four categories:

(1) Surface methods (flooding, border, basin, furrow)
(2) Sprinkler (center-pivot, self-propelled, fixed or solid set, portable)

(3) Drip
(4) Subirrigation

Losses associated with each category vary widely depending on the conditions under which they are used. Thus, each system can be most efficient for a particular soil, slope, crop, water quality, wind pattern, etc. Nonetheless, certain generalizations apply to the types of losses and overall efficiencies and applicability of these methods (Table 11-3).

Drip irrigation and subirrigation can be efficient irrigation methods in delivering water to the root zone with minimal losses. However, their applicability to the conditions at IID may be limited by local soil conditions, water quality (i.e., salinity), and the lack of familiarity of most local irrigators with these methods. Where they have been used extensively (e.g., Israel, Kuwait, and parts of the San Joaquin Valley), they have proven to be extremely efficient, saving significant quantities of water and resulting in greatly increased yields. These systems require pressurized (±25 psi) conveyance systems and filtration to prevent clogging the orifices and emitters. Widespread use of drip and subirrigation in Imperial Valley is seen as a long-term probability because of the relatively high capital and initial labor requirements. Drip irrigation systems are especially adapted to the higher value crops on the sandier type soils and on the steeper slopes where furrow irrigation is more difficult to manage. Drip irrigation is less attractive with inexpensive irrigation water on relatively level, heavier type soils and with the lower value crops. It is, therefore, recommended that a pilot project investigate the adaptability of these methods to various local soils and crops for a 3- to 10-year period.

Sprinkler systems can be efficient if properly selected and used. Under the climatic conditions of Imperial Valley, nighttime automatic operation should require the use of down-spray sprinklers. However, this condition limits the applicable types of sprinklers to center-pivot and self-propelled linear systems. A high-pressure delivery system would be required.

The following factors could contribute to the increased use of low-water-demand irrigation methods:

(1) Install pilot-scale irrigation systems of the major types enumerated above for the variety of crops grown at the IID. These pilot plots could be used on farms of local growers who agree to cooperate with the District personnel applying the systems and operating them to their normal performance specifications. Records would be kept to evaluate labor requirement, water use, application efficiency, yield, quality, etc.

(2) Provide incentives for the widespread use of systems found most conserving and applicable to IID conditions, on a dynamic basis, as those conditions change in the future. These incentives might include low-interest equipment loans, assistance with startup of new systems, provision of troubleshooting assistance, and loans of innovative irrigation equipment to farmers unwilling to risk a commitment to the long-term use of unfamiliar technology.

Table 11-3 - Properties of Various Irrigation Methods in Imperial Valley

Method	Uniformity	Losses: Deep Leaching	Losses: Tailwater Runoff	Losses: Evaporation	Adaptability: Crop	Adaptability: Slope
Surface						
Furrow	Fair-good	Moderate	Moderate	High	All	Uniform, less than 2%
Border	Good-excellent	Moderate	Moderate	High	Field	Uniform, less than 2%
Basin	Excellent	Moderate	Very low	High	All	Flat
Flood	Poor	Possibly high	Low	High	Field	Uniform, gentle
Sprinkler						
Portable (day)	Good	None-low	Very low	Very high	All, except some vegetables	Gentle, rolling
Self-propelled (night)	Good	None-low	None	Low	All, except some vegetables	Uniform, gentle
Center pivot (night)	Good	None-low	None	Low	All, except some vegetables	Relatively flat
Drip	Good	Controllable	None	None	Widely spaced crops	No limitation
Subirrigation	Good	Low-moderate	None	None	Ornamentals, closely spaced crops	No limitation

Source: Parsons, 1985.

(3) Encourage manufactures of low-water demand irrigation systems to establish local plants, warehousing, and distribution networks.

(4) Subsidize farmers using water-conserving irrigation systems.

11.6.2 BENEFITS AND COSTS

As discussed in section 11.5, up to 0.5 million AF/year may be conserved with a combination of irrigation method improvement and irrigation scheduling, based on soil, crop, and climatic data. The estimate of water savings presented here is based on a Districtwide application of the most appropriate irrigation systems, designed and operated at their most efficient performance conditions. It is important to ascertain that irrigation efficiency is not obtained at the expense of uniformity of application and crop water needs, which is why the use of high technology devices and methods must be introduced with a full understanding of the agronomic and economic requirements as they pertain to the local conditions. Because this blending of advanced techniques with agronomic and economic conditions requires much time, training, and possibly several trail-and-error cycles, the apparently high estimate of water savings must be regarded as an ultimate potential, possibly by the year 2010.

11.7 ENVIRONMENTAL CONSIDERATIONS

The on-farm water conservation methods discussed in this chapter include structural and nonstructural methods that are intended to more efficiently use the water delivered to the farmer and, thus, reduce operational wastes. All of the methods would result in less water flowing into the drains, but the salinity would be higher. Less flow entering the drains would reduce flows through the New and Alamo Rivers and, ultimately, would reduce flows into the Salton Sea. The rate at which salinity is increasing in the Salton Sea depends on the salinity and volume of flow into the sea, as well as on the rate of evaporation. Increased salinity of inflow into the sea and decreased dilution of the Salton Sea because of the decreased inflow volume would increase the rate of salinity rise in the sea.

Wetlands would receive less water from seepage. Subsection 9.1.3 discusses the environmental concerns relating to terrestrial and aquatic biota, including the impacts relating to decreased drain flow and seepage. Of particular concern are the Finney-Ramer Units of the Imperial Valley Wildlife area located on 8 miles of the Alamo River. These units could be affected by less seepage and reduced flow into the Alamo River.

Decreased water consumption would also cause lower flow in canals and laterals. Present high flows in canals cause scouring in canal bottoms that reduces aquatic plant and benthic macroinvertebrate populations. Decreased flows could cause an increase in these communities. Seepage from canals could also be reduced, or at least the seepage water table would be lowered. This would decrease the amount of water available to wetland and riparian vegetation and/or would increase the depth at which phreatophyte root systems would have to grow to reach water. This could result in a change in species distribution and composition in response to the change in the physical conditions.

Construction impacts could result from land leveling, tailwater pumpback, head ditch lining, and low-water-demand irrigation methods. Environmental concerns could include an increase in air emissions, noise impacts, transportation impacts, cultural resources, and others. These impacts would probably be of a short duration and not significant.

Most of the methods would have beneficial socioeconomic impacts on water conservation, although some would require high initial capital and labor requirements. This is especially true of low-water-demand irrigation methods. Head ditch lining would result in a reduction in maintenance costs. Low-water-use crop selection would have negative socioeconomic impacts because the most widely grown crop (alfalfa) is the most water demanding. Attractive incentives would be required to have farmers change to less water-demanding crops.